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CHARACTERIZATION OF FUEL CONSUMPTION
AND HEAT PULSE INTO THE MINERAL SOIL ON
THE JACOB BRANCH AND DEVIL DEN UNITS IN
NORTH CAROLINA

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HEAT PULSE INTO THE MINERAL SOIL ON THE
JACOB BRANCH AND DEVIL DEN UNITS
IN NORTH CAROLINA

FINAL REPORT

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AND

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Measured duff reduction compared to predicted values from CONSUME.

1.0 INTRODUCTION

Management proposes to increase the use of prescribed burning to prepare low-quality, mixed-hardwood sites for conversion to mixed-pine stands on steep slopes of the southern Appalachians. With this increased burning activity comes the concern for smoke pollution and fire impact on immediate and long-term nutrient capital, site productivity, water quality, and erosion.

A 4-year study by the staff at the Coweeta Hydrologic Laboratory, was conceived in 1987, to evaluate the practice of prescribed slash burning on steep slopes of the southern Appalachians. The study was designed to provide an improved understanding of prescribed fire impact on the net aboveground productivity and nutrient uptake, export of sediments and nutrients from the site, and litter-soil processes regulating nutrient cycling and future site productivity (Swift and others 1991). With a slight modification of the study, a thorough characterization of fuel consumption, heat pulse into organic and mineral soil layers, and emissions produced was added to the study design to enhance assessments. The Coweeta Lab invited the Fire and Air Resource Management Project^{1/} to participate in the study and to measure these variables. With the support of the U.S. Environmental Protection Agency and a subcontract with the Intermountain Research Station (Missoula, MT) for on-site emissions sampling, the Fire and Air Resource Management Project completed the task. Subsequent information provided not only a stronger study, but also the first fuel-consumption modeling and emission factor development

^{1/} The Fire and Air Resource Management Project is now the Fire and Environmental Research Applications Group under the Global Environmental Protection Program of the Pacific Northwest Research Station.

modeling for southern Appalachian hardwood fuel types. Emissions data measured during each of the prescribed burns will be provided in a separate report.

2.0 STUDY AREA

Three clearcut study sites were selected from forested lands on the Wayah Ranger District of the Nantahala National Forest. The sites were chosen by personnel from the Coweeta Hydrologic Laboratory and Wayah Ranger District. The Jacob Branch East and Jacob Branch West units were located 2 miles northwest of Franklin, North Carolina. The Devil Den unit was located 8 miles north of Franklin. Figure 1 displays unit locations.

Overstory vegetation of the units chosen for the study was mainly scattered, low-quality, mixed hardwood (Quercus coccinea and Quercus prinus) and pitch pine (Pinus rigida). Shrub understory was mainly Kalmia latifolia. The Jacob Branch units were located at about 2,600 feet in elevation, with westerly exposures and slopes averaging 35 percent. The Devil Den unit was located at 3,400 feet in elevation, with a westerly exposure and an average slope of 40 percent.

Trees and understory vegetation were cut in July and August, and left to dry on all three sites. Generally, fuels were distributed uniformly across each site. The units were burned in September, after the woody material had a chance to partially cure.

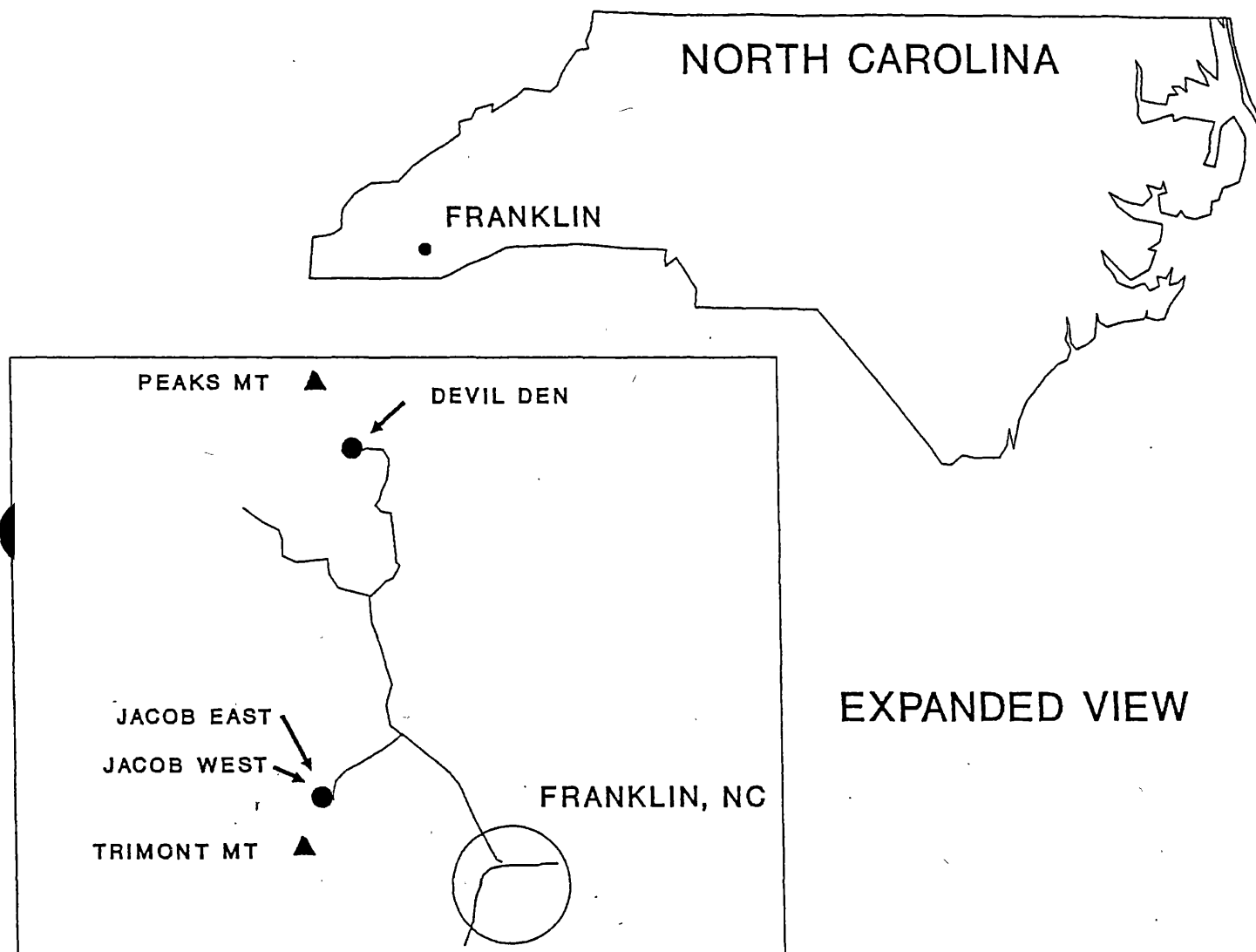


Figure 1. Location of study units.

3.0 METHODS

The Fire and Air Resource Management Project coordinated with the Coweeta Hydrologic Laboratory to establish fuel loading and fuel consumption plots on selected study units. Preburn inventory was completed on all units by the end of August, 1990. The units were burned September 18-21, 1990. Postburn inventory occurred immediately after each burn. Data collected from each unit included preburn fuel loading, weather, fuel moisture, woody fuel and duff consumption, and heat penetration into the forest floor and soil.

3.1 Fuel Inventory

Eighty semi-permanent plots were established at each of the three study sites. Plots were established in a systematic grid for complete coverage of the site. Randomly selected, 50-foot transect lines were directed from each plot for woody fuel measurements. This resulted in 4,000 feet of line-intersect inventory per unit (Brown 1974).

Additionally, 18 permanent plots were positioned near lysimeter plots established by the Coweeta Laboratory. A permanent, randomly selected, 50-foot transect line was directed from each plot for measurement of woody fuel consumption (figures 2-5). Duff pins were positioned around each of the 18 permanent plots to measure the forest floor.

3.1.1 Small woody fuels

Fuels 0- to 1/4-inch in diameter were tallied along 3.3 feet of each permanent transect line, beginning at the permanent plot center. The 1/4- to 1-inch material was inventoried along 6.6 feet of the permanent transect line, while the 1- to 3-inch fuels were tallied along the entire 50-foot length. This resulted in 59 feet of line intersect for the 0- to 1/4-inch fuels, 118 feet of line inventory for the 1/4- to 1-inch fuels and 900 feet of line inventory for the 1- to 3-inch fuels. Density data tables from the Wood Handbook (1974) and fuel loading formulas derived by Brown (1974) were used to calculate total loading in these fuel-size classes on a per-acre basis.

3.1.2 Large woody fuel and duff

Diameter measurements were recorded from each log intersected by the 80 transect lines radiating from the semi-permanent and permanent plots. Diameter measurements were used to calculate loadings of the large woody fuels using the line-intersect inventory method (Brown 1974). Sixteen duff-depth measurements were collected around each permanent plot for a total of 288 measurements per unit.

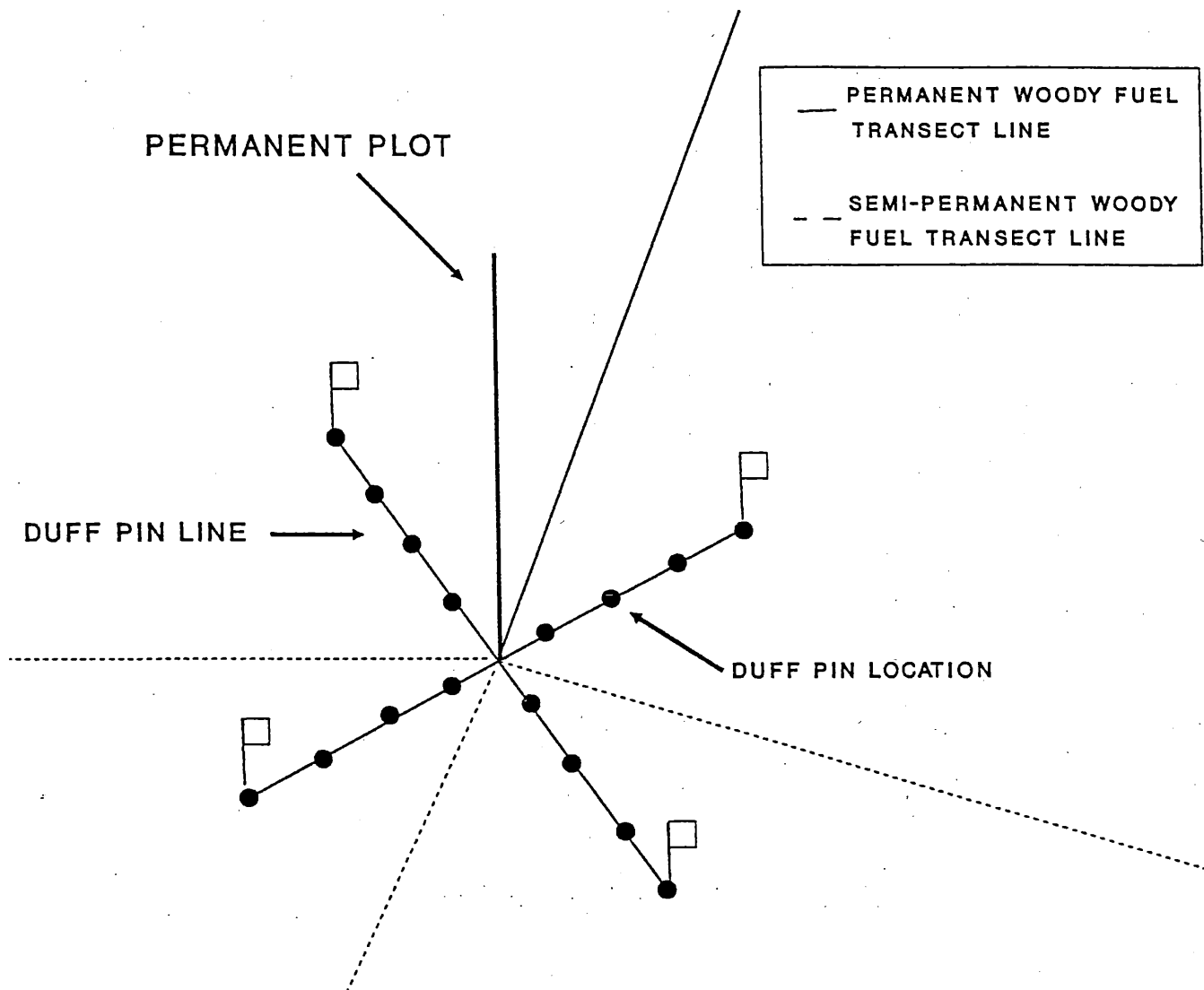


Figure 2. Permanent plot setup.

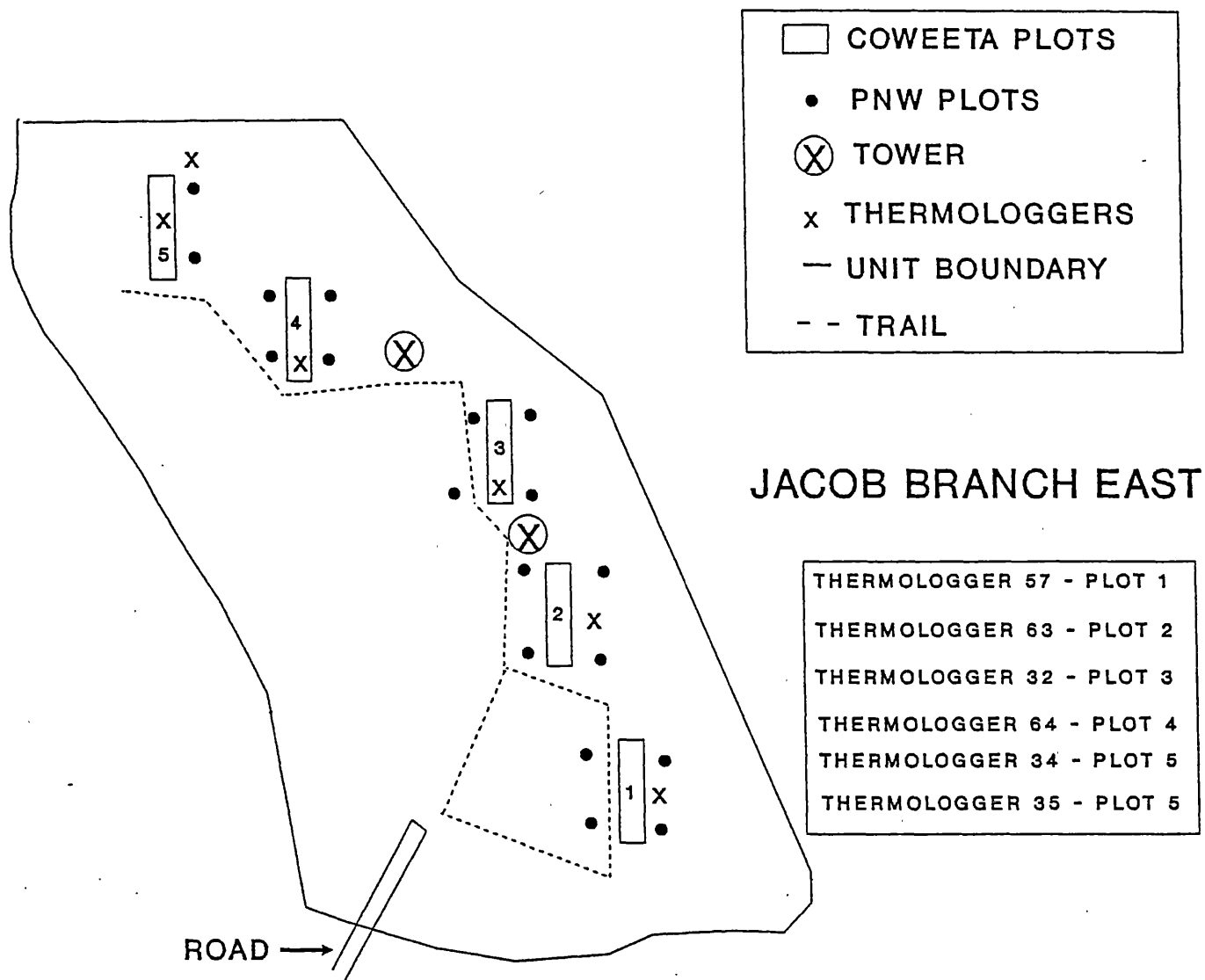


Figure 3. Permanent plot setup for Jacob Branch East.

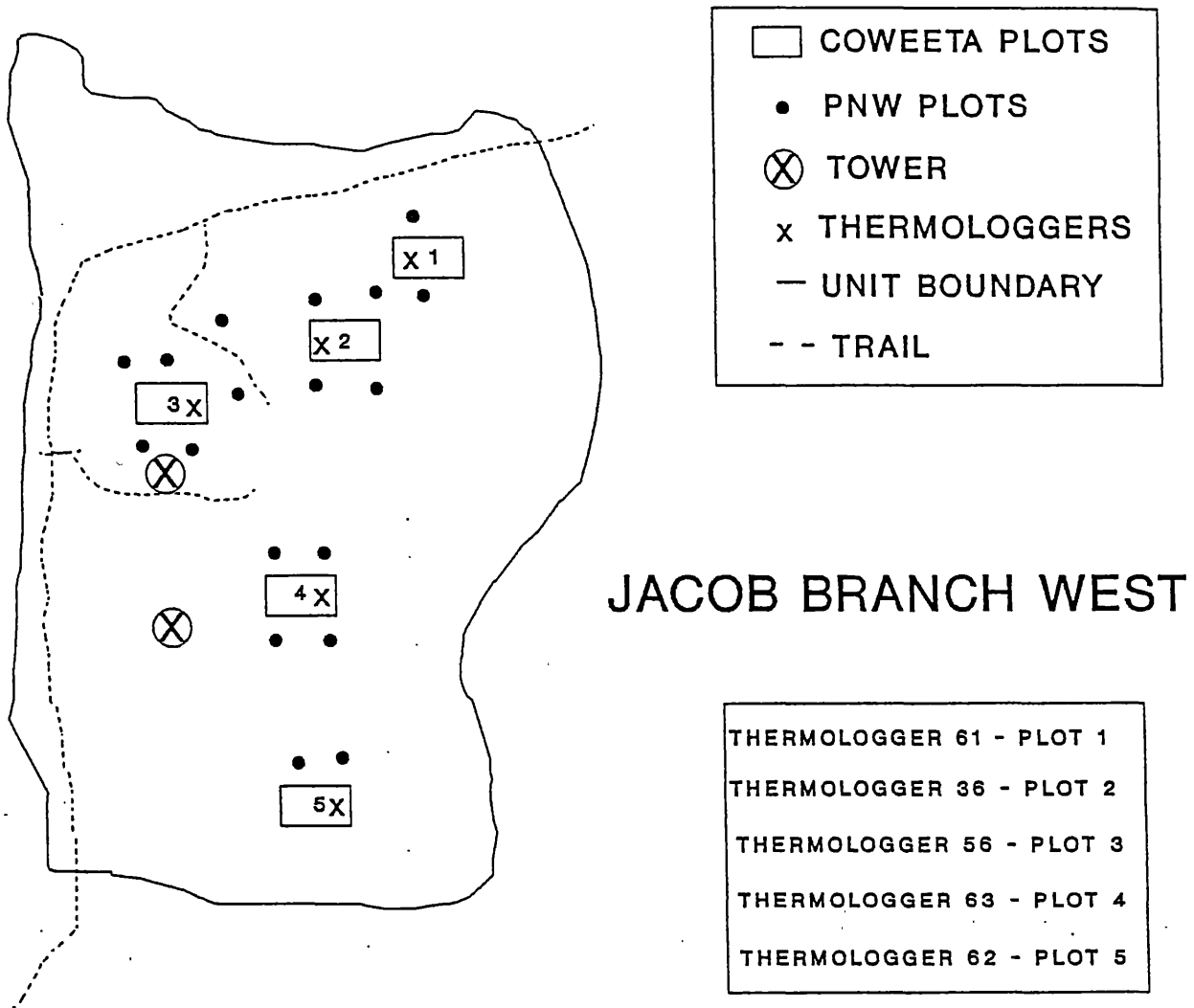


Figure 4. Permanent plot setup for Jacob Branch West.

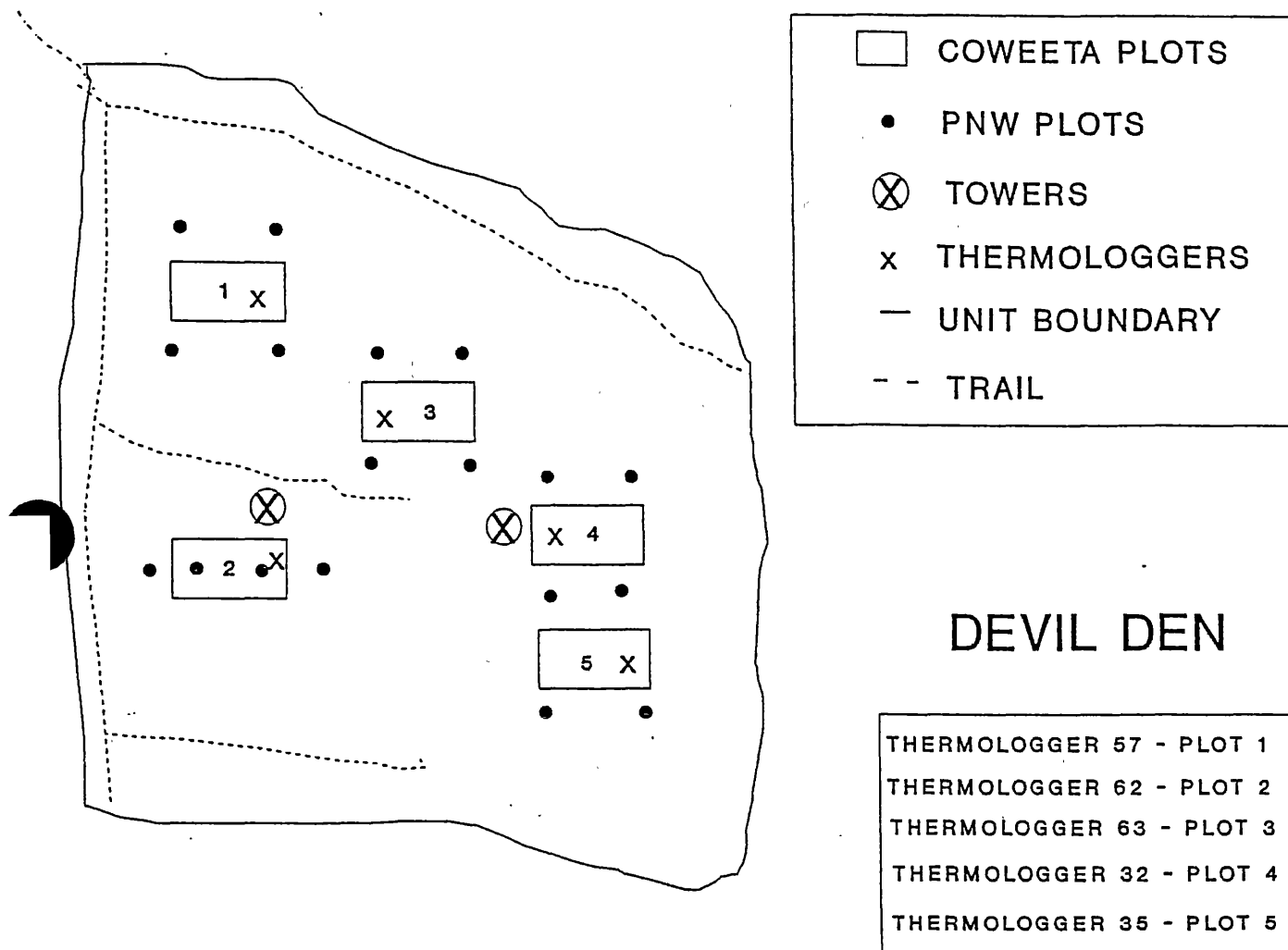


Figure 5. Permanent plot location for Devil Den.

3.2 Fuel and Soil Moisture

Average moisture content for woody fuels was determined from two samples collected from each of the wired logs just before the burn. In addition, 35 fuel moisture samples from the 1/4- to 1-inch fuels and 25 samples from the 1- to 3-inch fuels were collected. All samples were oven dried at 100 °C for 48 hours.

Average duff moisture for each unit was collected from 18 samples. The samples were collected from around each duff-consumption plot. If a distinct dry layer on top of a wet layer was found in the duff profile, a sample from each layer was collected and dry-layer depth was recorded. All samples were oven-dried at 70 °C for 96 hours.

One soil moisture sample was collected from each of the 18 permanent plot. The samples were oven-dried at 100 °C for 48 hours.

A 3- to 9 inch large fuel moisture content was predicted using a moisture model called the ADJ-Th (Ottmar and Sandberg 1985). On-site weather variables, including maximum and minimum temperature and humidity, and precipitation, were acquired from the Coweeta Laboratory weather stations.

3.3 Weather

A belt weather kit was used to collect on-site weather variables of relative humidity, temperature, and wind speed every 15 minutes during the burn. In addition, precipitation duration, precipitation total, and maximum and minimum daily temperature and relative humidity data were collected from the Coweeta on-site weather stations. This data was used to predict large fuel moisture content and fuel consumption from a computer program called CONSUME (Peterson and Ottmar 1991).

3.4 Fuel Consumption

3.4.1 Small woody fuel

Consumption of the 0- to 1/4-inch and 1/4- to 1-inch fuels was determined by subtracting the preburn loading from the postburn loading. A postburn loading was calculated by using fuel-loading formulas, density tables, and a postburn inventory tally along the permanent transect lines. Consumption of the 1- to 3-inch fuels was determined by converting the measured reduction in the diameter of large woody fuels to a percent-volume reduction and applying the result to the preburn loading.

3.4.2 Large woody fuel

Consumption of large woody fuels was measured as diameter reduction (which was converted to volume reduction) from 30 randomly chosen logs, 3 to 9 inches in diameter (Sandberg and Ottmar 1983). Wires attached to numbered tags for log identification were tightly wrapped around the logs before burning and were cinched up after burning. Exposed wire lengths were measured to determine circumference reduction which was converted to diameter reduction. The logs intersected fuel-inventory transect lines established at the 18 permanent plots.

3.4.3 Duff

Duff consumption was measured as depth reduction. Sixteen metal spikes or clay tile strips, called duff pins, were inserted flush with the duff layer around each permanent plot (Beaufait and others 1977). Total duff reduction was determined in the field by measuring the exposed length of duff pin following the fire. Total duff depth was determined by measuring the distance between the top of the pin and the mineral soil. Duff included the fermentation layer (Oe) and the humus layer (Oa). A total of 288 duff pins were placed on each unit.

3.5 Heat Penetration into the Duff and Soil

Units treated with fire were measured with thermologgers for heat-pulse penetration and duration through the duff and mineral soil. The thermologgers

integrate three high-temperature thermocouple sensors with a 3-channel recorder which is designed to withstand fire conditions and to use very little energy. Installed before the burn, the recorder sleeps until the temperature at the uppermost sensor, which is placed in the slash, reaches 70 °C. The instrument then goes into recording mode and all three sensors are recorded every 60 seconds.

A single thermologger was placed near each lysimeter plot established by Coweeta personnel (refer to figures 3-5 for locations). The thermologger was placed in a narrow hole excavated by a post-hole digger. The highest sensor was positioned 2 inches above the litter-layer surface in the slash. The second and third sensors were positioned in the duff or mineral soil, using a "jig" to keep the probes parallel and in place (figure 6).

Following each burn, the thermologger sensors were excavated and locations recorded with respect to duff and mineral soil profiles. The data recorded by the thermologger was removed and data stored on a portable computer. The thermologgers were then refitted with new batteries and positioned in the next unit scheduled for burning.

Variation in temperature pulses throughout the broadcast burns were going to require additional temperature data beyond what could be supplied by the limited number of thermologgers. Therefore, 6-inch clay tiles, painted with temperature sensitive paints which melt at 60 °C or 45 °C, were used to determine the depth of heat penetration. A total of 192 clay pins were positioned in each broadcast burn. These pins were also used to measure duff reduction.

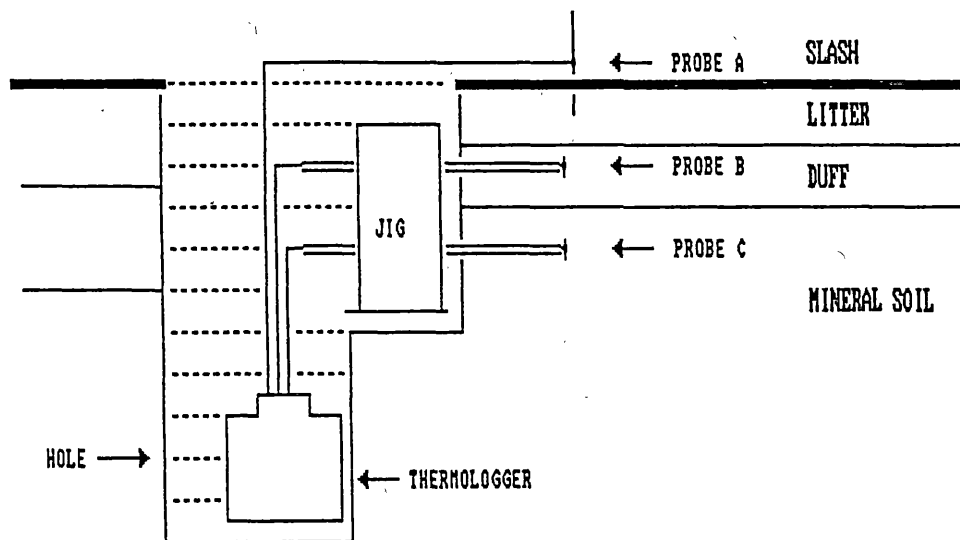


Figure 6. Thermologger placement.

4.0 RESULTS

4.1 Fuel Loading

Loadings for small and large woody fuels, and duff depths, varied between units (table 1); they were very similar to loadings and duff depths common to logged areas of the Pacific Northwest (figure 7). Loadings of the 0- to 1-inch woody fuels ranged from 15.4 tons per acre on Jacob Branch East to 11.7 tons per acre on Jacob Branch West. Loading of the 1- to 3-inch fuels ranged from 17.0 tons per acre on the Jacob East unit to 10.1 tons per acre on the Devil Den unit.

Large woody fuels (greater than 3 inches in diameter) ranged from 41.5 tons per acre on Jacob Branch East to 18.1 tons per acre on Devil Den.

The average duff depth ranged from 1.46 inches on the Devil Den unit to 0.83 inch on the Jacob Branch West unit. This would amount to 17.5 and 10.0 tons per acre when using a duff bulk density of 12.0 tons/(acre·inch) (Sandberg and others 1989).

4.2 Fuel Moisture

Moisture contents for small fuels varied between units because of differences in elevation, aspect, and days since significant rainfall (table 2). The last rain had fallen during September 12-15, when precipitation amounted to approximately 1.5 inches of rain over a duration of 16 hours.

Table 1. Unit and preburn fuel data summary for study units.

Unit	State	Land Owner	Elevation Feet	Aspect	Slope Percent	PREBURN FUELS						
						0-1"	1-3"	>3" Sound	Total Woody	Duff	Duff	Total
						T/A	T/A	T/A	T/A	Inches	T/A	T/A
Jacob Branch East	NC	USFS	2600'	W	35-50	15.4	17.0	41.5	73.9	1.30	15.6*	89.5
Jacob Branch West	NC	USFS	2500'	SW	30-40	11.7	10.3	29.2	51.2	0.83	10.0*	61.2
Devil Den	NC	USFS	3400'	SW	35-45	15.0	10.1	18.1	43.2	1.46	17.5*	60.7

* Based on conversion factor of 12.0 tons/acre/inch of duff.

PREBURN FUELS

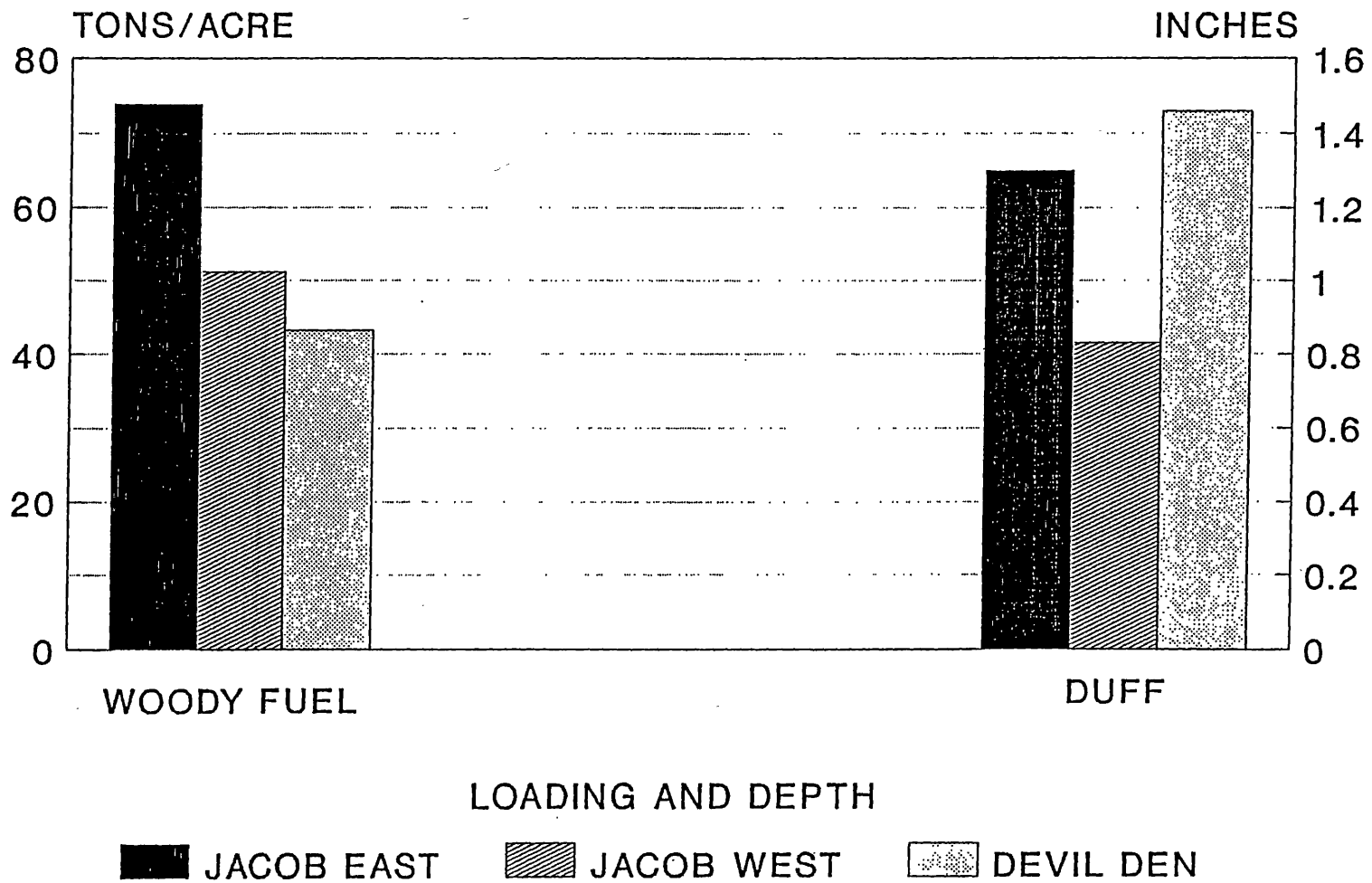


Figure 7. Woody fuel loading and duff depth comparisons between research areas.

Jacob Branch East was burned when 3 days had elapsed since significant rainfall. Moisture content for 1/4- to 1-inch fuels averaged 23 percent, while the 1- to 3-inch fuels had a moisture content of 30 percent.

Jacob Branch West was burned when 4 days had elapsed since significant rainfall. The 1/4- to 1-inch material averaged 16 percent moisture content while the 1- to 3-inch fuels averaged 23 percent. In both cases, fuel moisture was 7 percent lower than recorded at Jacob's Branch East.

Although the Devil Den unit had 2 more days of drying than the Jacob units, higher elevation and cooler temperatures resulted in higher fuel moisture contents. The 1/4- to 1-inch fuels averaged 28 percent, while the 1- to 3-inch fuels averaged 38 percent.

Woody fuels greater than 3 inches in diameter varied slightly between units. Average large-fuel moisture contents were 49 percent for Jacob Branch East, 44 percent for Jacob's Branch West, and 46 percent for Devil Den. Fuel moisture contents which range from 45 to 49 percent indicate live-fuel moisture was probably still present in the fuels. In other words, the larger fuels had not dried long enough to be cured. Generally, fuel moisture contents of 44 percent or lower indicate the live-fuel moisture has been removed and moisture content fluctuates only because of atmospheric conditions.

Duff moisture contents ranged from 99 percent on Devil Den to 59 percent on Jacob Branch West. Higher elevation at Devil Den probably accounted for the greater duff moisture level. Soil moisture contents averaged a low 36 percent

on the Devil Den unit; this was 9 percent lower than was recorded on Jacob East and 10 percent lower than was measured on Jacob Branch West.

4.3 Weather

No extreme weather conditions were noted during the study burns. High humidities in the morning required units to be ignited following fog dissipation.

4.4 Fuel Consumption

The 0- to 1-inch fuels were completely consumed on all three study sites (table 3 and figure 8). The 1- to 3-inch fuels varied from a consumption of 98 percent on Jacob Branch East to 84 percent on Devil Den which corresponded to 16.7 tons per acre at Jacob Branch East to 8.5 tons per acre at Devil Den.

Diameter reduction of large woody fuels (greater than 3 inches in diameter) ranged from 1.15 inches on Jacob Branch East to 0.46 inch on Devil Den, resulting in a consumption of 12.7 tons per acre and 2.6 tons per acre, respectively.

Total woody fuel consumption ranged from a high of 44.8 tons per acre on Jacob Branch East to a low of 24.9 tons per acre on Jacob Branch West. Percent woody fuel consumption ranged from 60 to 49 percent.

Table 3. Fuel-consumption summary for study units.

Unit	Date Burned	Lighting Tech.	FUEL CONSUMPTION										Heat Depth** (For 60 C) Inches	Heat Depth** (For 45 C) Inches
			0-1"	1-3"	>3" Diameter Reduction*	>3" Fuel Consumption*	Total Woody Consumption	Total Woody Consumption Percent	Duff Reduction	Percent Duff Reduction	Duff Consumption@	Total Fuel Consumption		
			T/A	T/A	Inches	T/A	T/A	Percent	Inches	Percent	T/A	T/A		
Jacob Branch East	09/18/90	HAND	15.4	16.7	1.15	12.7	42.5	57.5	0.87	66.9	10.4	52.9	1.8	2.3
Jacob Branch West	09/19/90	HAND	11.7	9.2	0.50	4.0	24.5	47.9	0.39	46.9	4.7	29.2	1.5	1.7
Devil Den	09/21/90	HAND	15.0	8.5	0.48	2.6	25.7	59.5	0.43	29.4	5.2	30.9	1.7	1.6(#)

* Based on all logs measured for fuel consumption regardless of fuel moisture content.
 ** Average heat penetration determined from temperature tiles.
 (#) Discrepancy due to low sample size for 45 degree C tiles.
 @ Based on conversion factor of 12.0 tons/acre/inch of duff.

FUEL CONSUMPTION

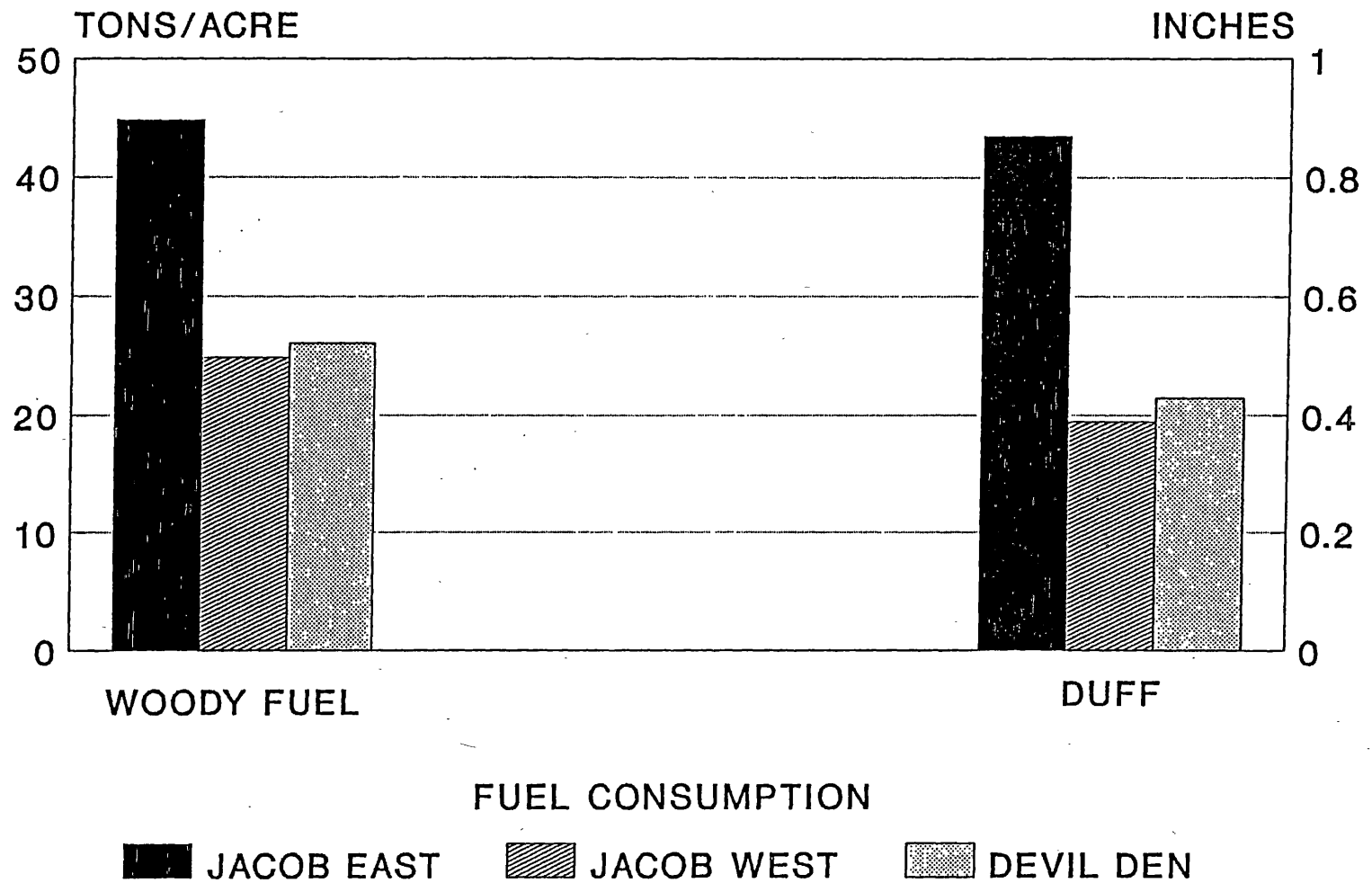


Figure 8. Comparisons of woody fuel consumption and duff reduction between research areas.

Duff consumption varied from a reduction of 0.87 inch on Jacob Branch East to 0.39 inch on Jacob Branch West. With a bulk density of 12.0 tons/(acre·inch) (Sandberg and others 1989), this would result in a duff consumption range of 10.4 tons per acre and 4.7 tons per acre.

4.5 Heat Pulse

Heat penetration into the duff and mineral soil determined from heat sensitive tile pins ranged from a unit average of 2.3 inches to 1.6 inches for 45 °C. The 60 °C temperature penetrated into the duff or mineral soil to a depth of 1.8 inches on the Jacob Branch East.

The real-time data recorded by the thermologgers indicated very low temperatures penetrated into the duff and mineral soil. All real-time data graphics from the thermologgers are presented in appendix A.

5.0 ANALYSIS AND DISCUSSION

The main objective of this final report is to report preburn fuel-loading, fuel-consumption, and heat-pulse measurements for each of the three broadcast prescribed burns established for the study. Discussion will be limited to those measurements and a comparison between measured and predicted woody fuel and duff consumption using available consumption equations. Characterization of emissions will be presented in a separate final report to be completed by September 1991.

5.1 Small Woody Fuel Consumption

The 0- to 3-inch fuels were nearly completely consumed on each of the three prescribed burns monitored. This is generally the case on steep units with relatively heavy fuel loadings which are burned in the summer or fall months. We were surprised, however, at the high fuel moisture content at which nearly 100 percent consumption was obtained. For example, moisture contents for the 1/4- to 1-inch fuels ranged between 16 and 28 percent. In short-needed slash, less than 80 percent of the small fuels will consume under those fuel moisture conditions. This indicates that the small woody fuels in hardwood fuel types tend to be more combustible at higher fuel moisture contents.

5.2 Large Woody Fuel Consumption

Diameter reduction of the large woody fuels was relatively low. This was due to the relatively high moisture content of these fuels, since large logs had not had time to completely cure after felling.

For large fuels, studies have shown moisture content is often a sufficient predictor of diameter reduction over a wide range of fuel types, including short-needed conifers and hardwoods in the Pacific Northwest. We visually compared the measured diameter reduction with the simple fuel-consumption model shown in figure 9. Diameter reduction of large fuels were predicted relatively well by the fuel-consumption model developed for Pacific Northwest woody fuels. We tried various statistical comparison techniques; however, the small sample size (3 units) did not allow a valid statistical conclusion.

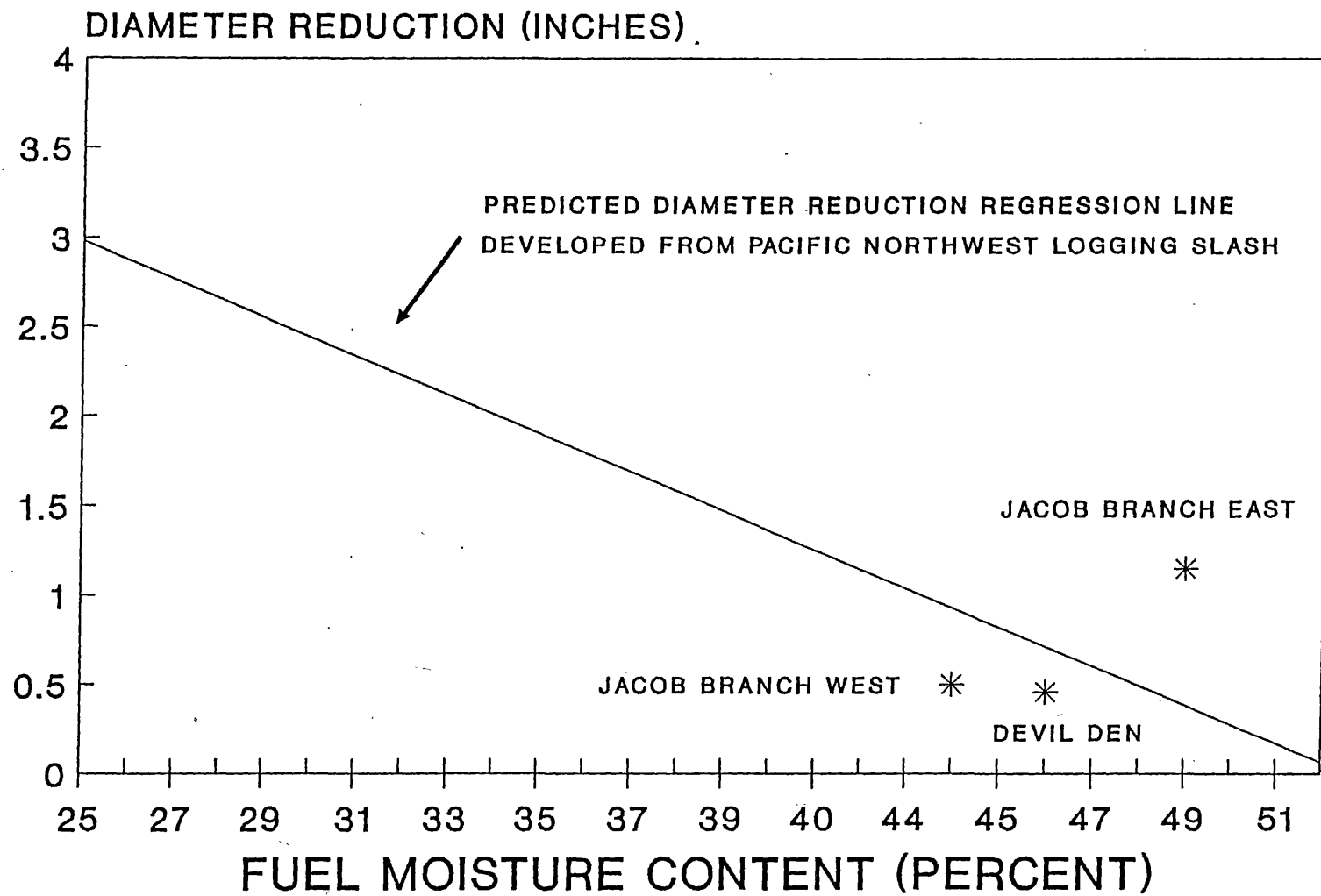


Figure 9. Diameter reduction versus fuel moisture content. Regression line for predicting diameter reduction has been added for comparison.

A computer software program, called CONSUME (Peterson and Ottmar 1991), has been developed which calculates woody fuel and duff consumption for prescribed burns in the Pacific Northwest. CONSUME accounts for fuel moisture content and several other variables which influence large-fuel consumption and duff consumption, such as the moisture content of uncured fuels and high-intensity fires. Both these additional characteristics were noted for all the prescribed fires measured during this study.

Measured preburn input variables were entered into the program from each of the research prescribed burns. CONSUME predicted the measured diameter reduction of large fuels within 0.2 inch (figure 10). This is well within the 0.3-inch-error bounds of the consumption models.

CONSUME predicted diameter reduction better than the diameter-reduction model, using only one variable because CONSUME accounts for uncured fuels and high-intensity fires, which was the classification of all three of the units.

5.3 Duff Reduction

Duff reduction was relatively small due to several factors. First, the duff layer was wet. Second, the prescribed fires were very intense, but for a very short duration of time. The heat from the consumption of the woody fuels did not last long enough to dry out the duff and allow for consumption. Third, duff reduction depends on large woody fuel consumption; and only 2.6 to 12.0 tons per acre were consumed on the units. Finally, the shallow duff probably contained a mixture of organics and mineral soil and mineral soil reduces the combustibility of the duff.

FUEL CONSUMPTION MEASURED VS PREDICTED

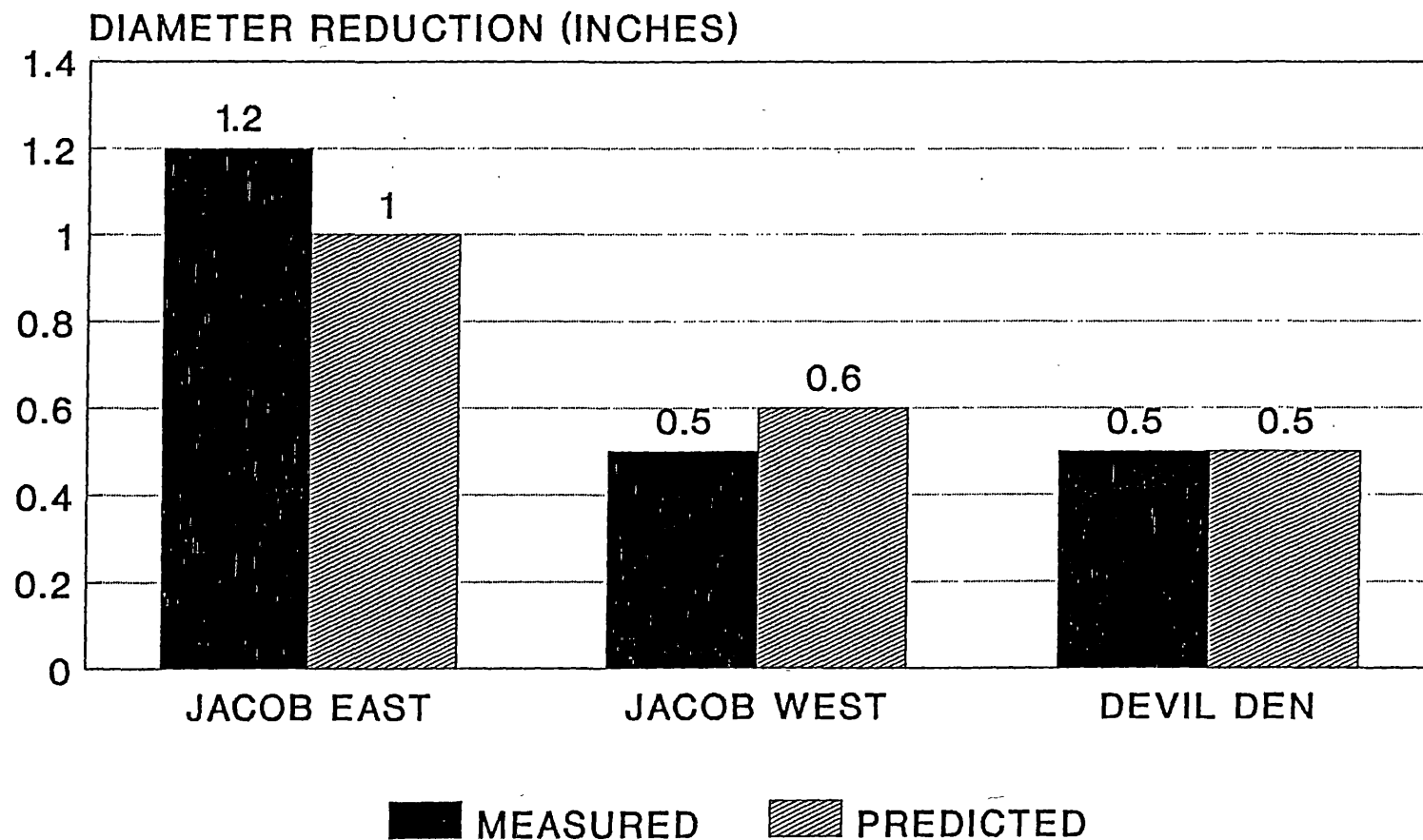


Figure 10. Measured diameter reduction compared to predicted value from CONSUME.

The model developed for shallow duff layers for westside Douglas-fir, western hemlock, and hardwood fuels predicted measured values very well (figure 11). This model considers all the above-mentioned variables. Again, statistical comparison tests were invalid because of the small sample size used for comparison.

Measured preburn input variables were entered into the program from each of the research prescribed burns. CONSUME (Peterson and Ottmar 1991) predicted measured duff reduction within 0.2 inch (figure 12). This is within the 0.3-inch-error bounds associated with the duff consumption model (Ottmar and others 1985).

Bulk density for duff on the research plots was assumed to be 12 tons/ (acre·inch). This was based on a combination of the findings by Sandberg and others (1989) and the bulk-density samples we collected from hardwood stands in the Pacific Northwest. Actual bulk densities will be collected from the control plots at the site and reported later.

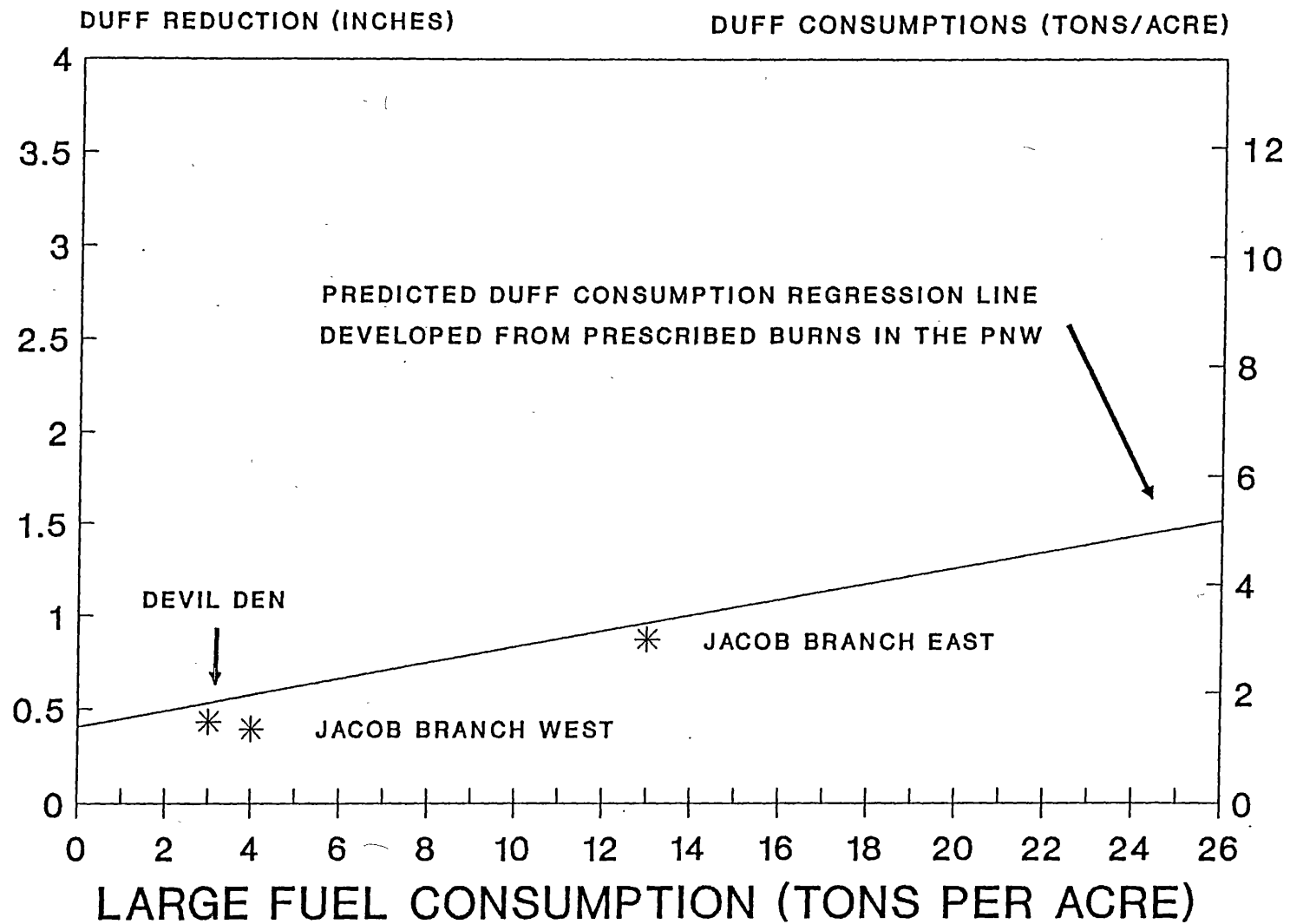


Figure 11. Duff reduction versus large-fuel consumption. Regression line for predicting duff reduction has been added for comparison.

FUEL CONSUMPTION MEASURED VS PREDICTED

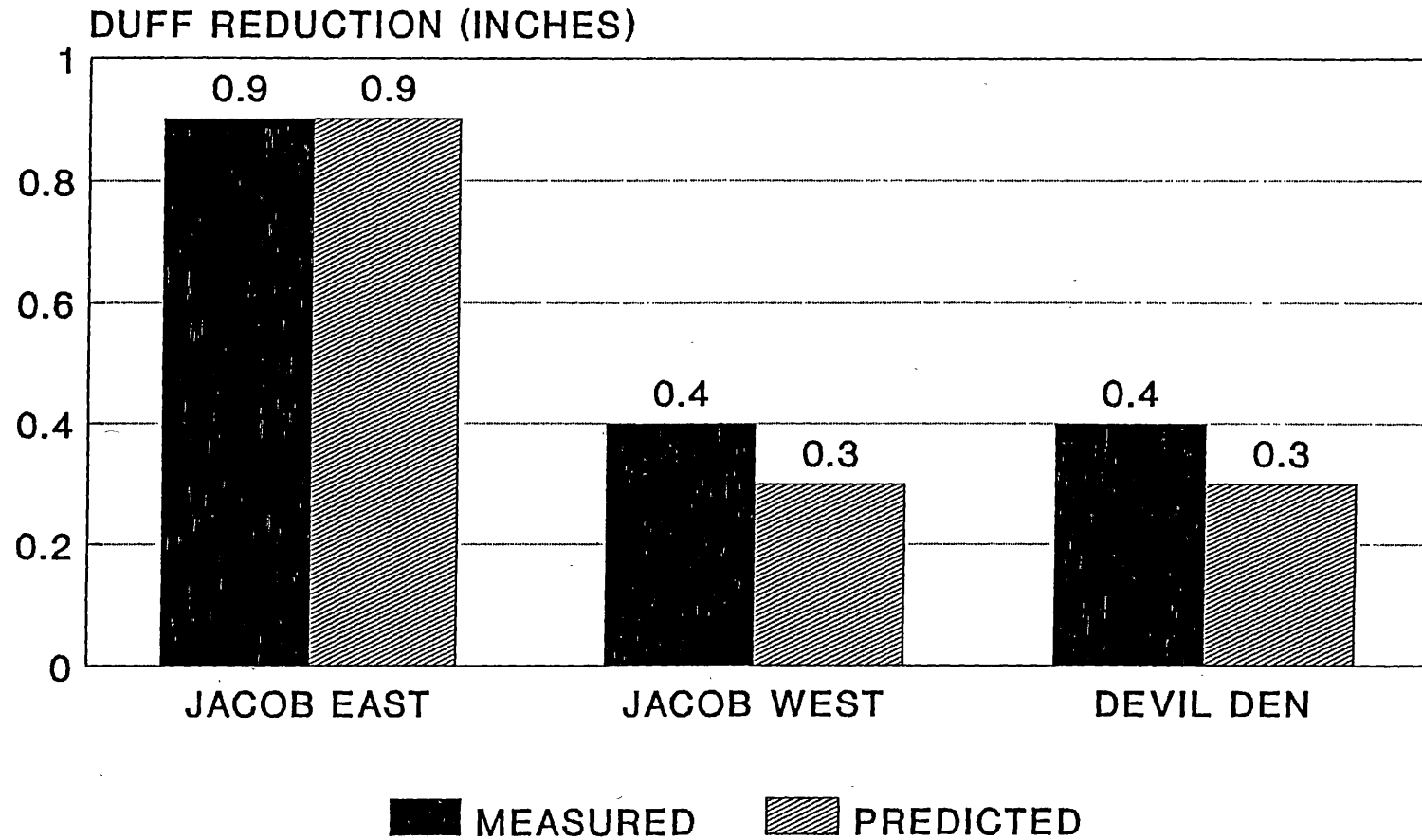


Figure 12. Measured duff reduction compared to predicted values from CONSUME.

5.4 Heat Pulse

Heat pulse into the remaining organic material and mineral soil was very weak (table 3). Temperature tiles and thermologgers indicated temperatures reached only 113 to 138 °F (45 to 60 °C) at 1 to 2 inches below the surface. All of the following contributed to limited heat penetration into the soil on the research sites:

1. Consumption of large fuels was minimal.
2. Fires were of high intensity and short duration.
3. Mineral soil and duff were moist.
4. Duff consumption was minimal.

6.0 CONCLUSION

As a result of this study, we have provided a detailed characterization of fuel loadings, fuel consumption and heat-pulse penetration into the duff and mineral soil for the Jacob East, Jacob West, and Devil Den prescribed burn units. This information will be used to supplement emission sampling data and provide an improved understanding of the impact of prescribed fire on net aboveground productivity and nutrient uptake, export of sediments and nutrients from the site, and litter-soil processes regulating nutrient cycling and future site productivity.

The study data has also been used to compare measured fuel moisture and fuel consumption with currently available fuel moisture and consumption model outputs. The models currently in CONSUME adequately predicted measured values in most cases.

The ability to predict fuel consumption, in combination with emission factors, will enable managers and regulatory agencies to inventory emissions (Peterson and Sandberg 1988) from hardwood conversion burns in the southern Appalachian region. It will also allow evaluation of emission-reduction techniques. A simple weather-zone network, along with acres burned, species, and preburn loading information from each burn, will allow a relatively accurate estimation of smoke produced.

7.0 RECOMMENDATIONS

Only three units were measured for fuel moisture and fuel consumption during this study. To complete a valid, statistical comparison between currently available models, an additional nine units would need to be monitored. However, the three data points we did collect indicate that the moisture model and fuel-consumption model do a relatively good job of representing moisture conditions and the combustion of biomass. We recommend, therefore, that the consumption models for Pacific Northwest hardwood fuel types, which are currently housed in the CONSUME program (Peterson and Ottmar 1991), be used for hardwood activity fuels in the southern Appalachian area, with the knowledge that further evaluation is warranted.

8.0 LITERATURE CITED

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9.0 GLOSSARY

ADJ-Th: The National Fire Danger Rating System predicted 1000-hour timelag fuel moisture content adjusted to represent an average unit fuel moisture.

CLEARCUT: A timber harvest method in which all, or nearly all, trees in a stand of timber are cut in one operation.

DIAMETER REDUCTION: Reduction in width of circular log caused by fire.

DUFF: Humus and other partially decayed material on the forest floor. We refer to the duff as the Oa and Oi layers.

EMISSIONS: A release into the outdoor atmosphere of air contaminants.

FUEL LOADING: The amount of fuel present, expressed quantitatively in terms of mass of fuel per unit area.

FUEL MOISTURE: The amount of water present in a fuel. Generally fuel moisture content is expressed as a percent of a material's oven-dry weight.

LARGE FUEL: Dead wood, consisting of sound roundwood, greater than 3 inches in diameter; large limbwood.

NFDR-Th: National Fire Danger Rating System predicted 1000-hour timelag fuel moisture.

1-HOUR FUELS: Dead wood, consisting of roundwood, 0 to 1/4 inch in diameter.

100-HOUR FUELS: Dead wood, consisting of roundwood, 1 to 3 inches in diameter.

PLANAR INTERSECT: A vertical sampling plane with no width along which all intersecting residue pieces are measured.

PRESCRIBED BURN: Controlled application of fire to wildland fuels in either their natural or modified state to obtain planned objectives of silviculture, wildlife habitat management, grazing, fire hazard reduction, and so forth.

SMALL FUEL: Dead wood, consisting of sound roundwood, 0 to 3 inches in diameter.

10-HOUR FUEL STICKS: A manufactured stick or set of sticks of known dry weight exposed to the weather and periodically weighed to determine changes in moisture content of the 10-hour fuels.

10.0 METRIC EQUIVALENTS

1 inch = 2.54 centimeters

1 foot = 30.48 centimeters

1 mile = 1.609 kilometers

1 acre = 0.4047 hectare

1 ton = 0.907 metric ton

11.0 SCIENTIFIC AND COMMON NAMES OF TREE SPECIES

Pitch pine	<i>Pinus rigida</i> Mill.
Scarlet oak	<i>Quercus coccinea</i> Muenchh
Chestnut oak	<i>Quercus prinus</i> L.
Mountain Laurel	<i>Kalmia latifolia</i> L.

12.0 APPENDIX A

HEAT PULSE GRAPHICS FROM PRESCRIBED BROADCAST BURNS

UNIT NAME: JACOBS BRANCH EAST

THERMOLOGGER #: 32

DEPTHS (MM)

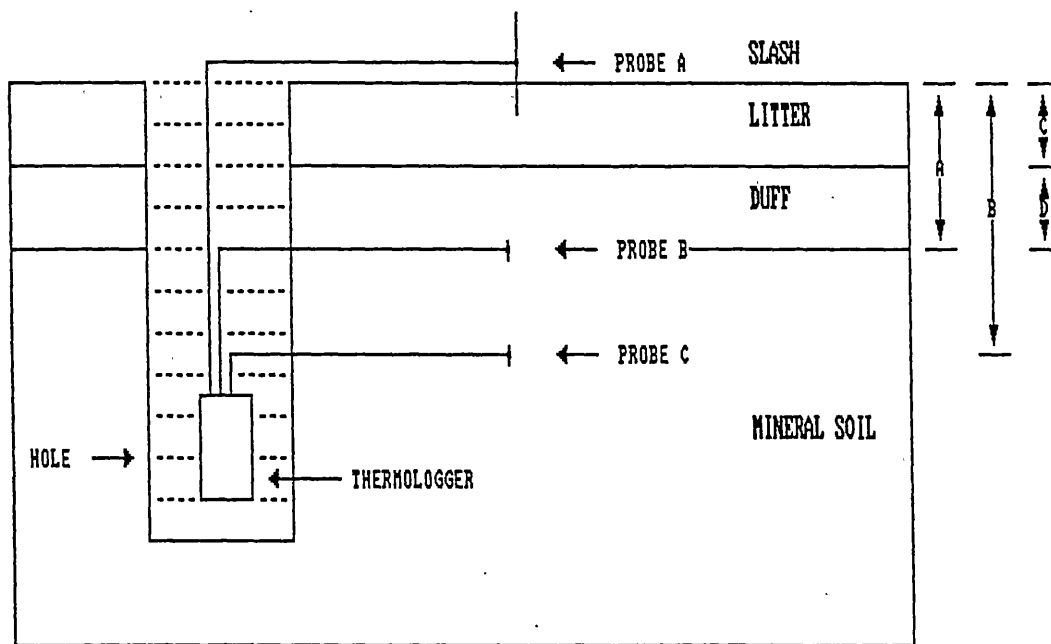
A: 42

COMMENTS: - PROBE 2 IS LOCATED AT THE DUFF/MINERAL SOIL
INTERFACE.

B: 67

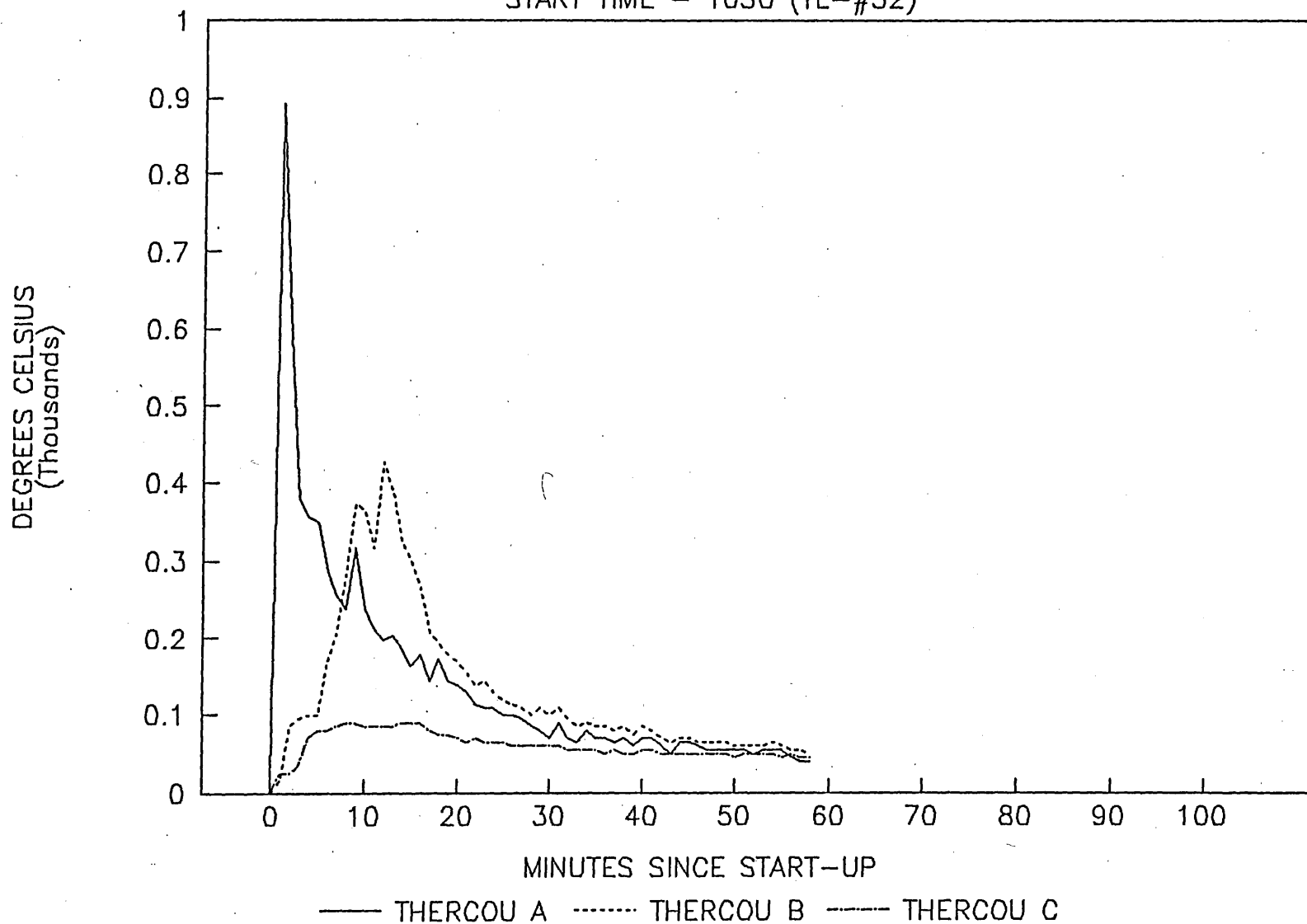
C: 22

D: 28



JACOBS EAST 9-18-90

START TIME - 1030 (TL-#32)



UNIT NAME: JACOBS BRANCH EAST

THERMOLOGGER #: 34

DEPTHS (MM)

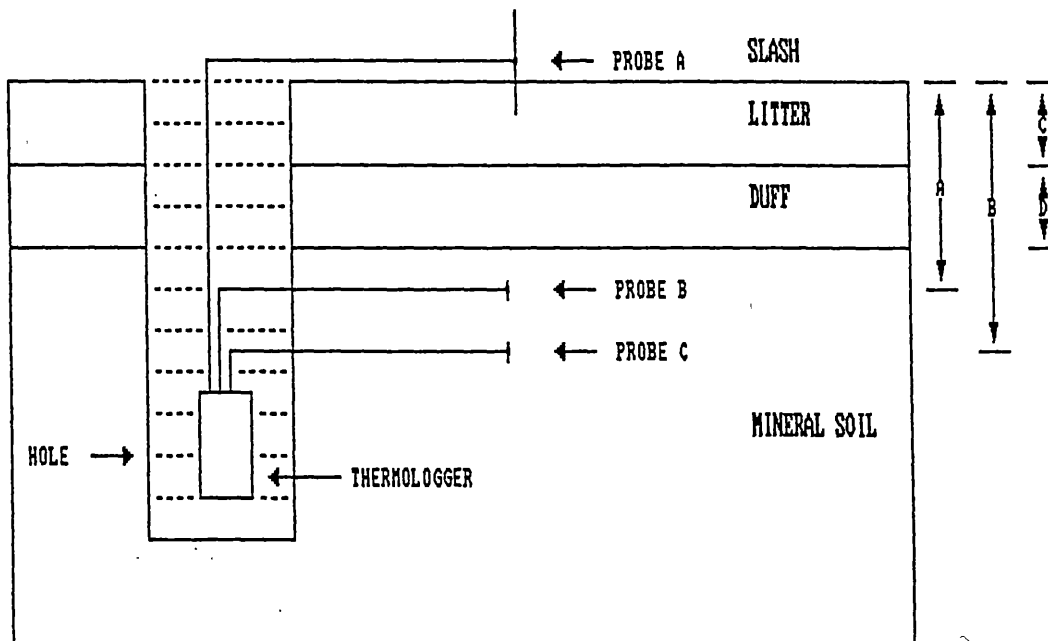
A: 48

COMMENTS:

B: 78

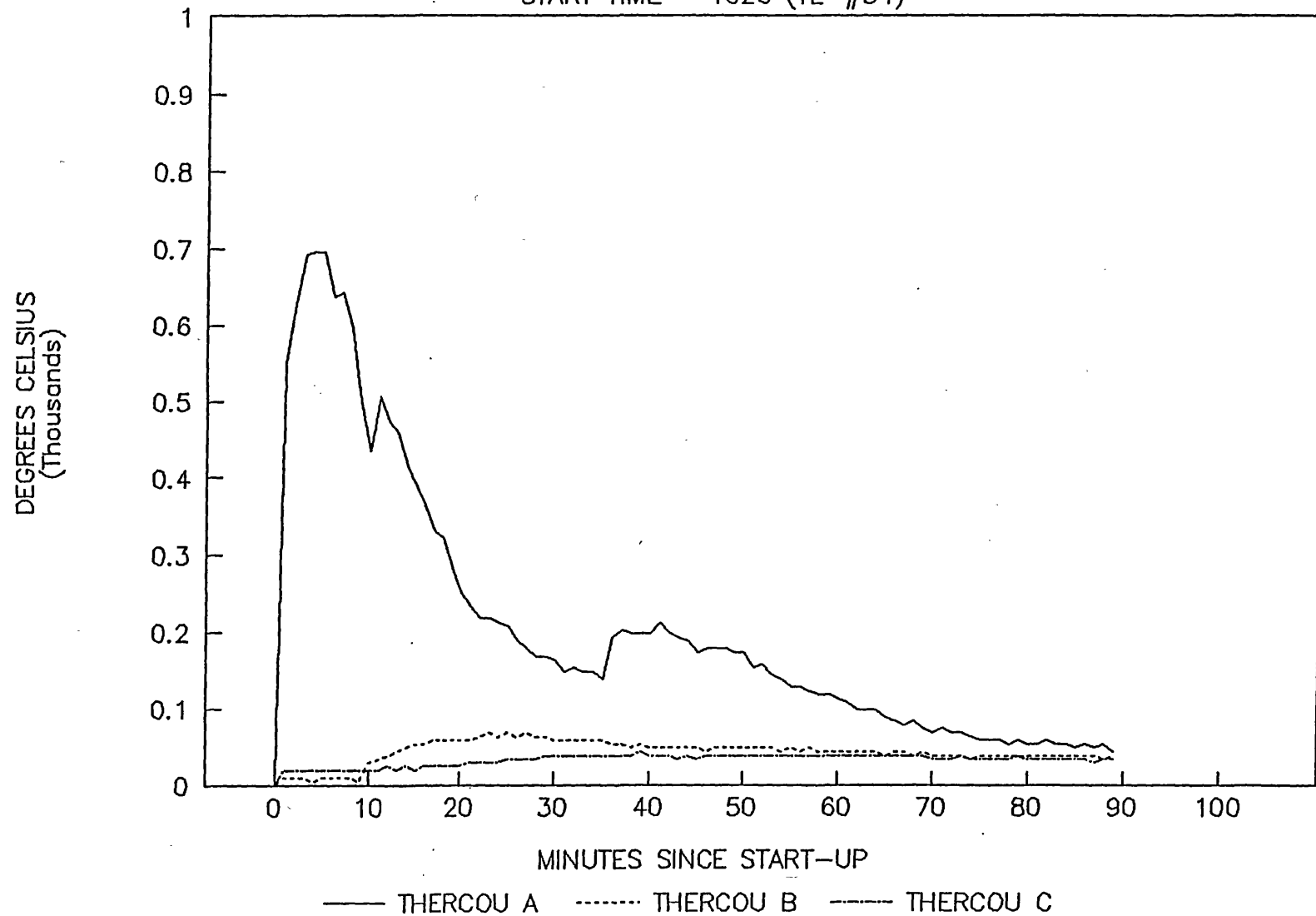
C: 15

D: 15



JACOBS EAST 9-18-90

START TIME - 1026 (TL-#34)



UNIT NAME: JACOBS BRANCH EAST

THERMOLOGGER #: 35

DEPTHS (MM)

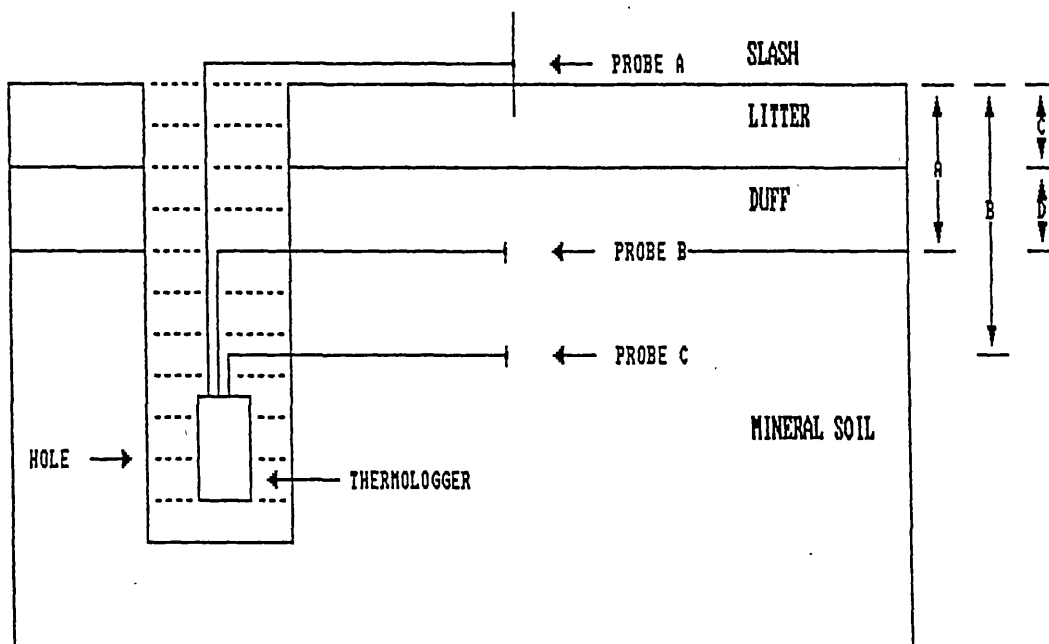
A: 55

COMMENTS: - PROBE 2 WAS POSITIONED AT THE DUFF/MINERAL SOIL
INTERFACE.

B: 88

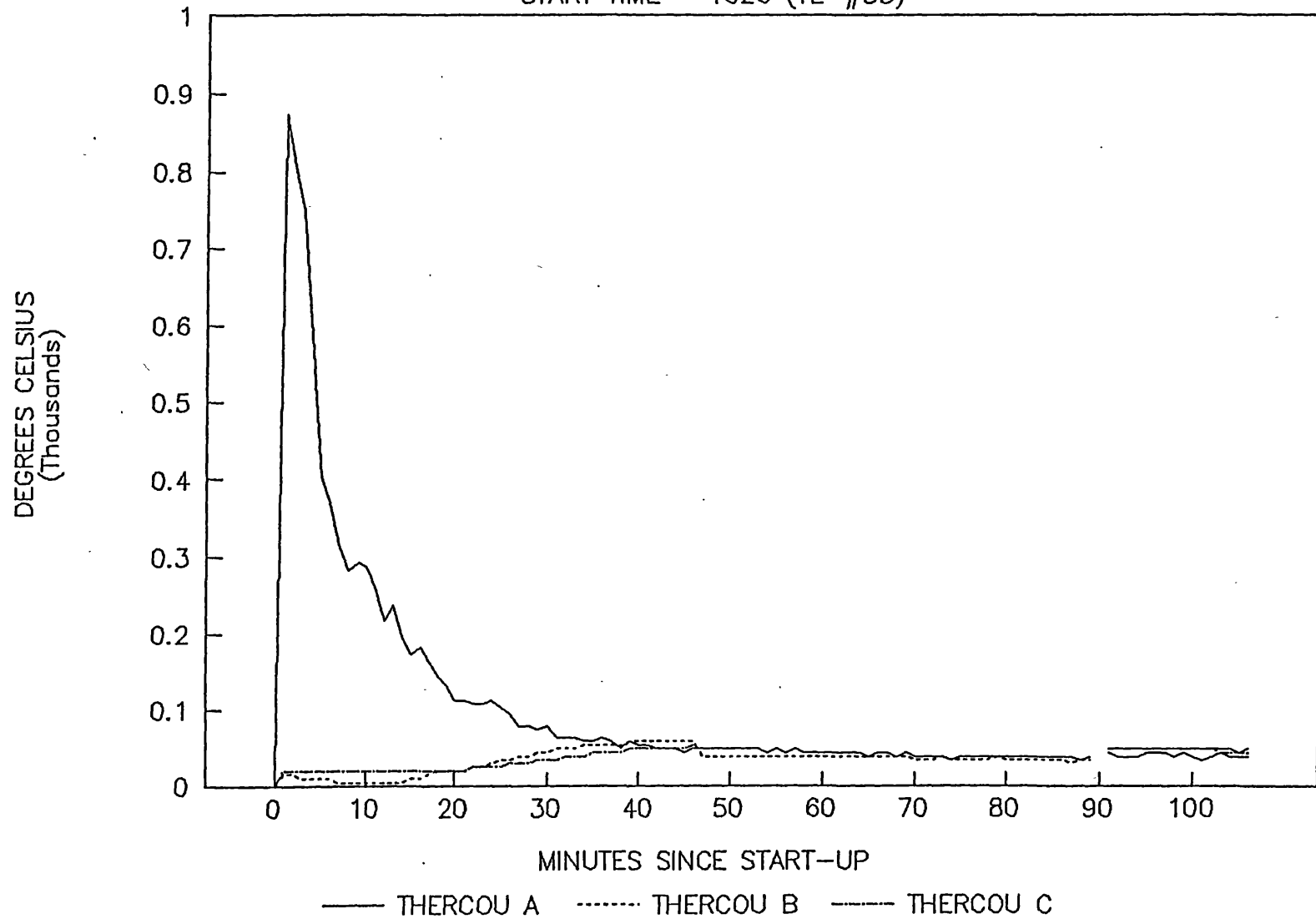
C: 18

D: 45



JACOBS EAST 9-18-90

START TIME - 1026 (TL-#35)



UNIT NAME: JACOBS BRANCH EAST

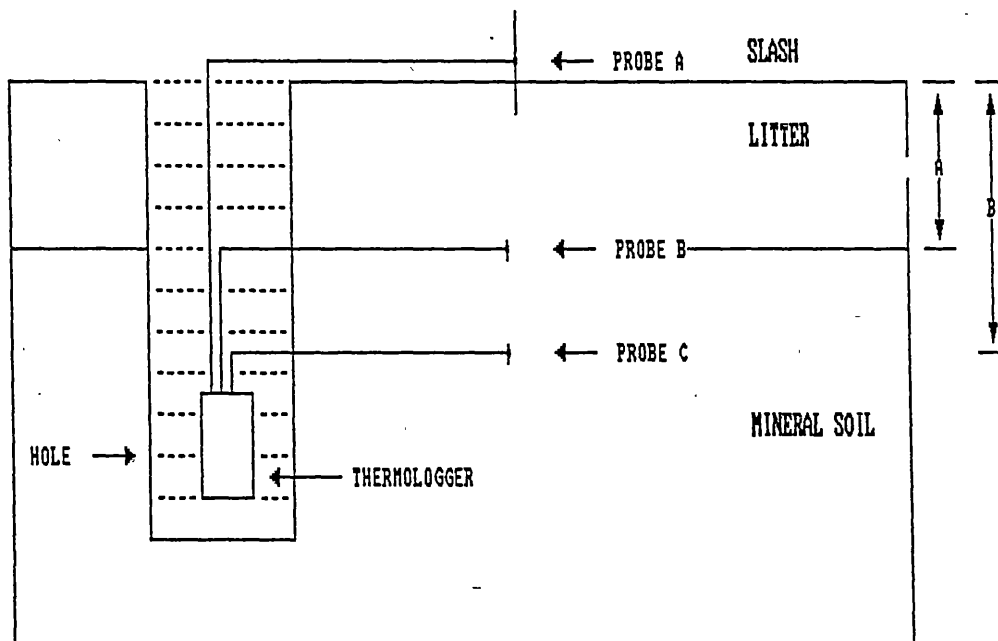
THERMOLOGGER #: 57

DEPTHS (MM)

A: 15

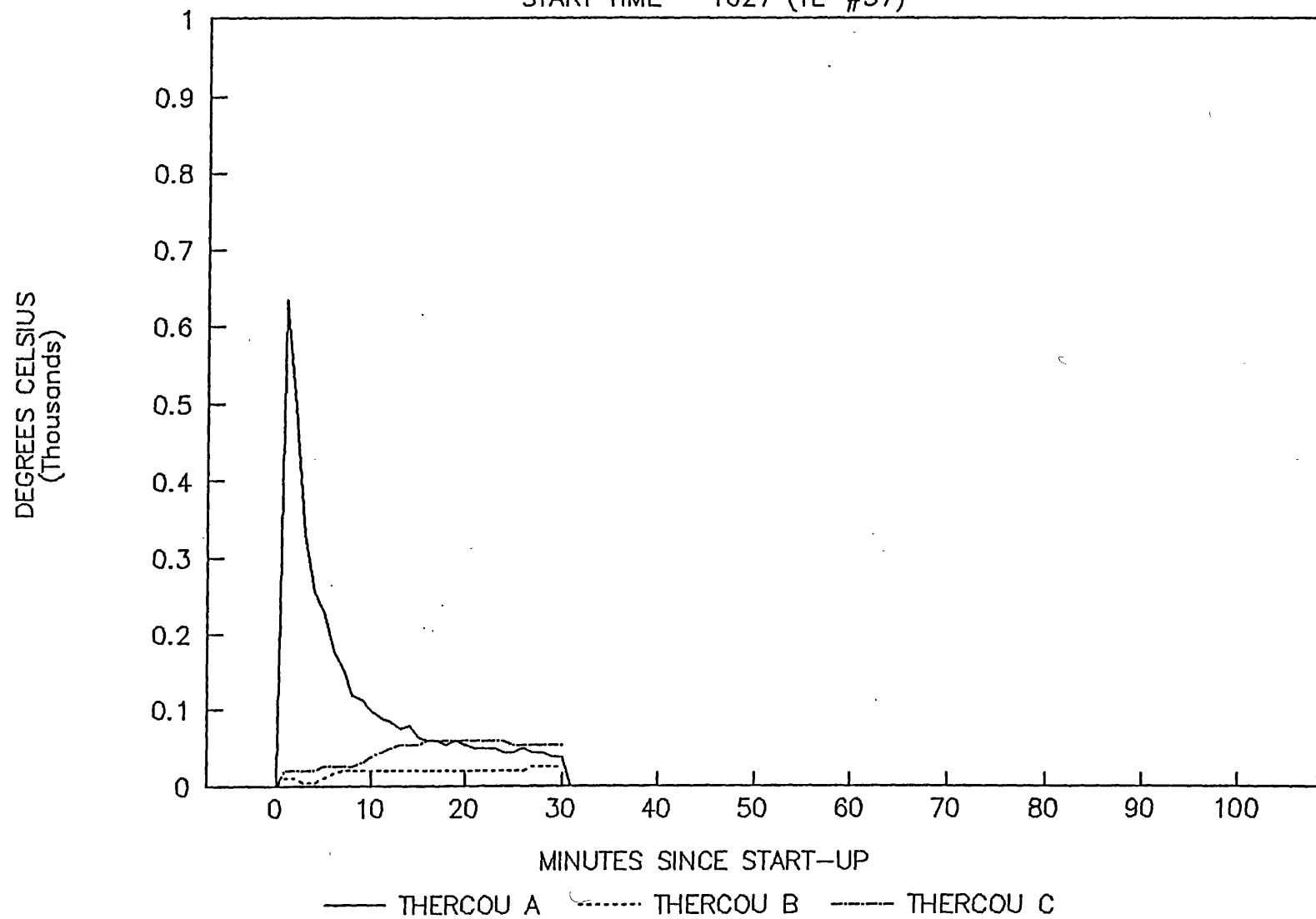
COMMENTS: - NO DUFF LAYER.

B: 55



JACOBS EAST 9-18-90

START TIME - 1027 (TL-#57)



UNIT NAME: JACOBS BRANCH EAST

THERMOLOGGER #: 63

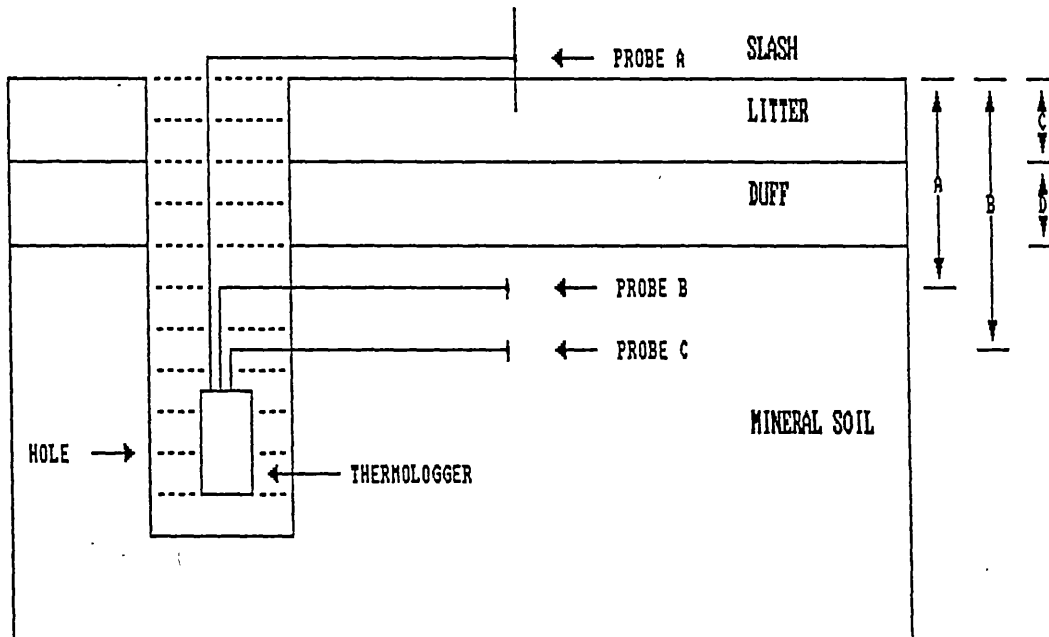
DEPTHS (MM)

A: 25 COMMENTS:

B: 58

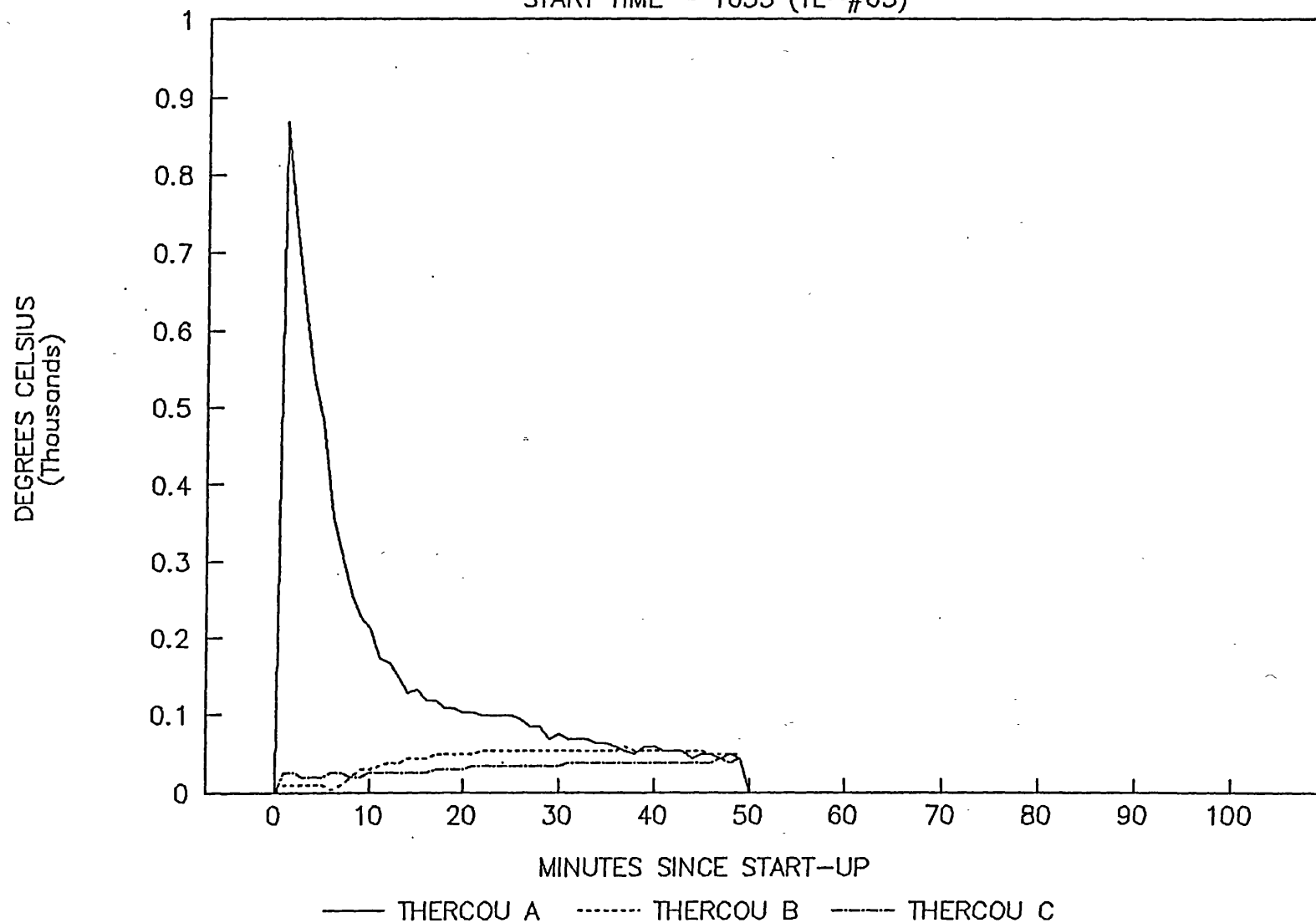
C: 8

D: 2



JACOBS EAST 9-18-90

START TIME - 1033 (TL-#63)



UNIT NAME: JACOBS BRANCH EAST

THERMOLOGGER #: 64

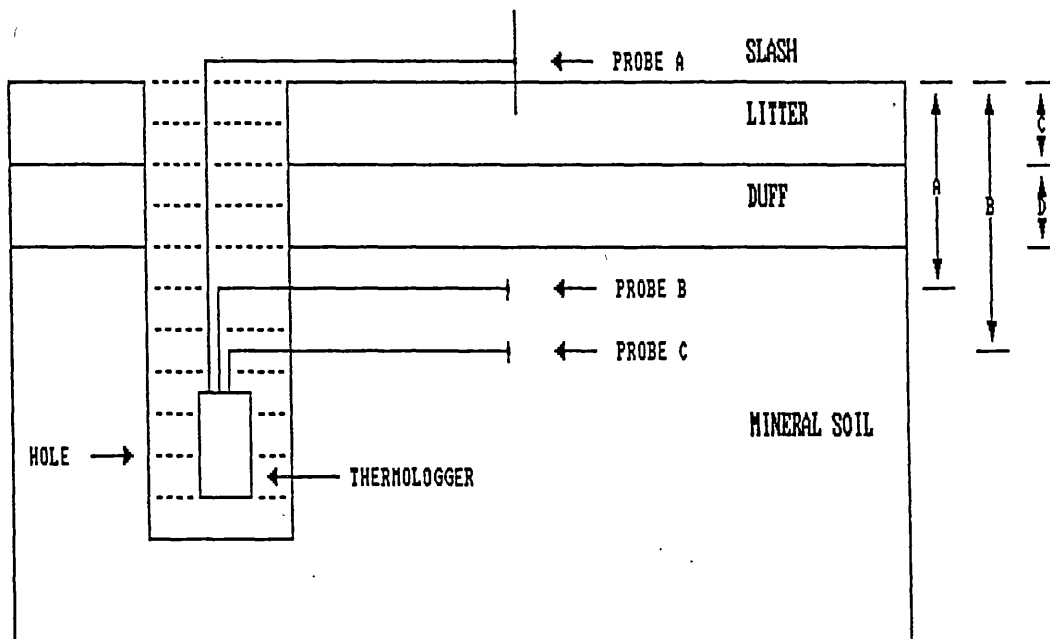
DEPTHS (MM)

A: 51 COMMENTS:

B: 81

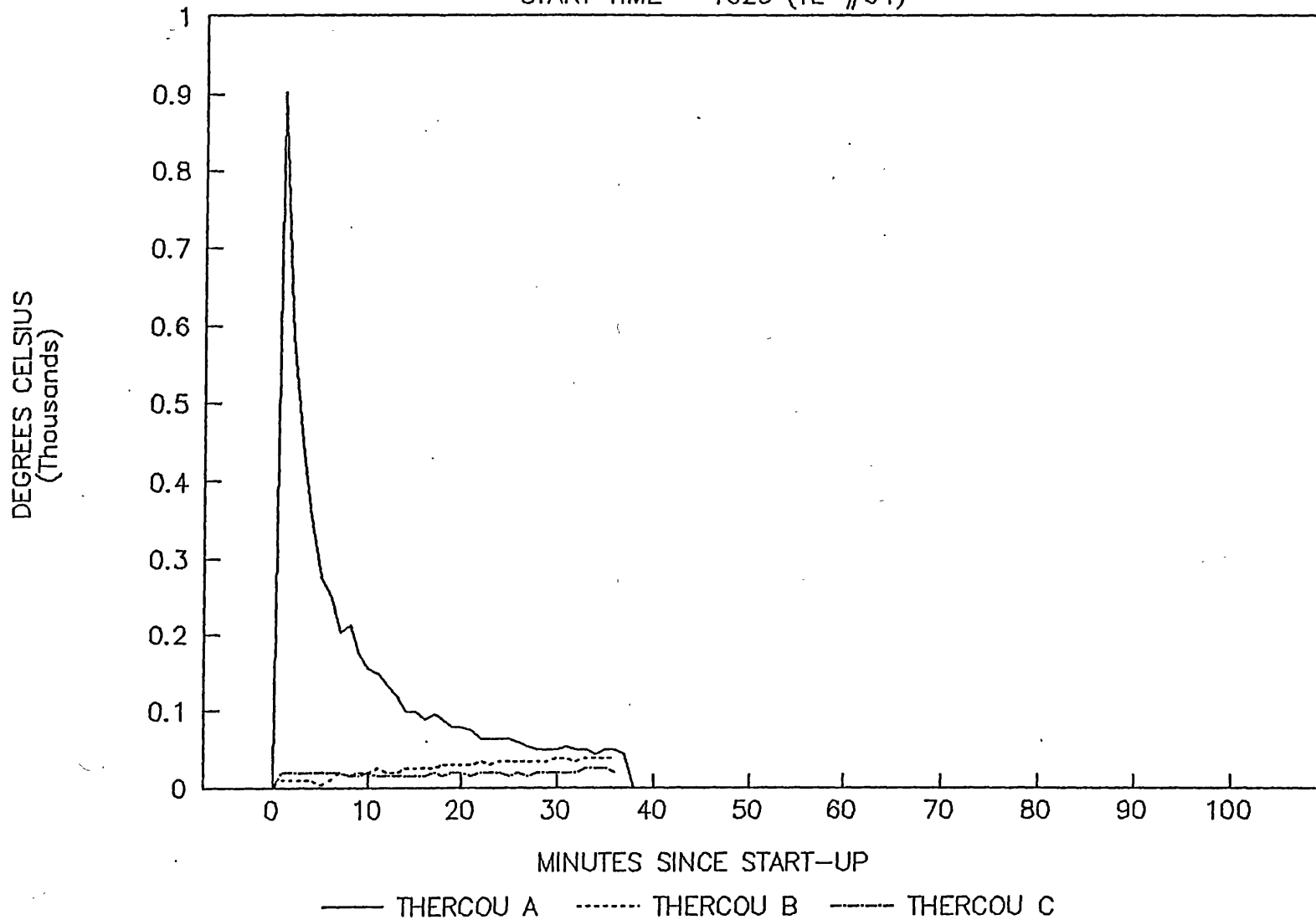
C: 12

D: 4



JACOBS EAST 9-18-90

START TIME - 1029 (TL-#64)



UNIT NAME: JACOBS BRANCH WEST

THERMOLOGGER #: 36

DEPTHS (MM)

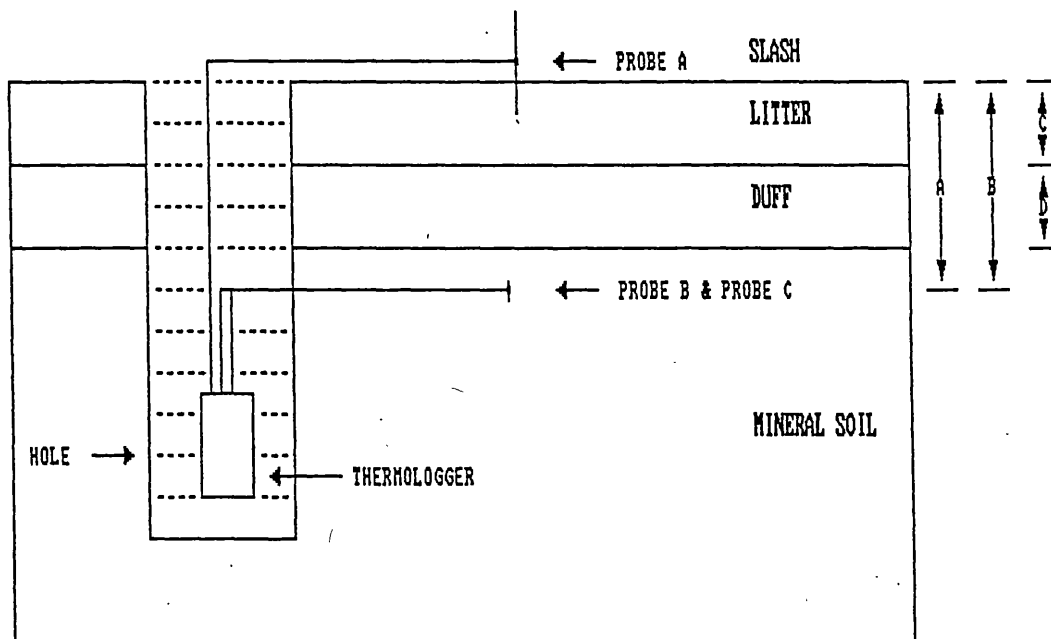
A: 45

COMMENTS: - PROBE 2 AND PROBE 3 LOCATED
AT SAME DEPTH.

B: 45

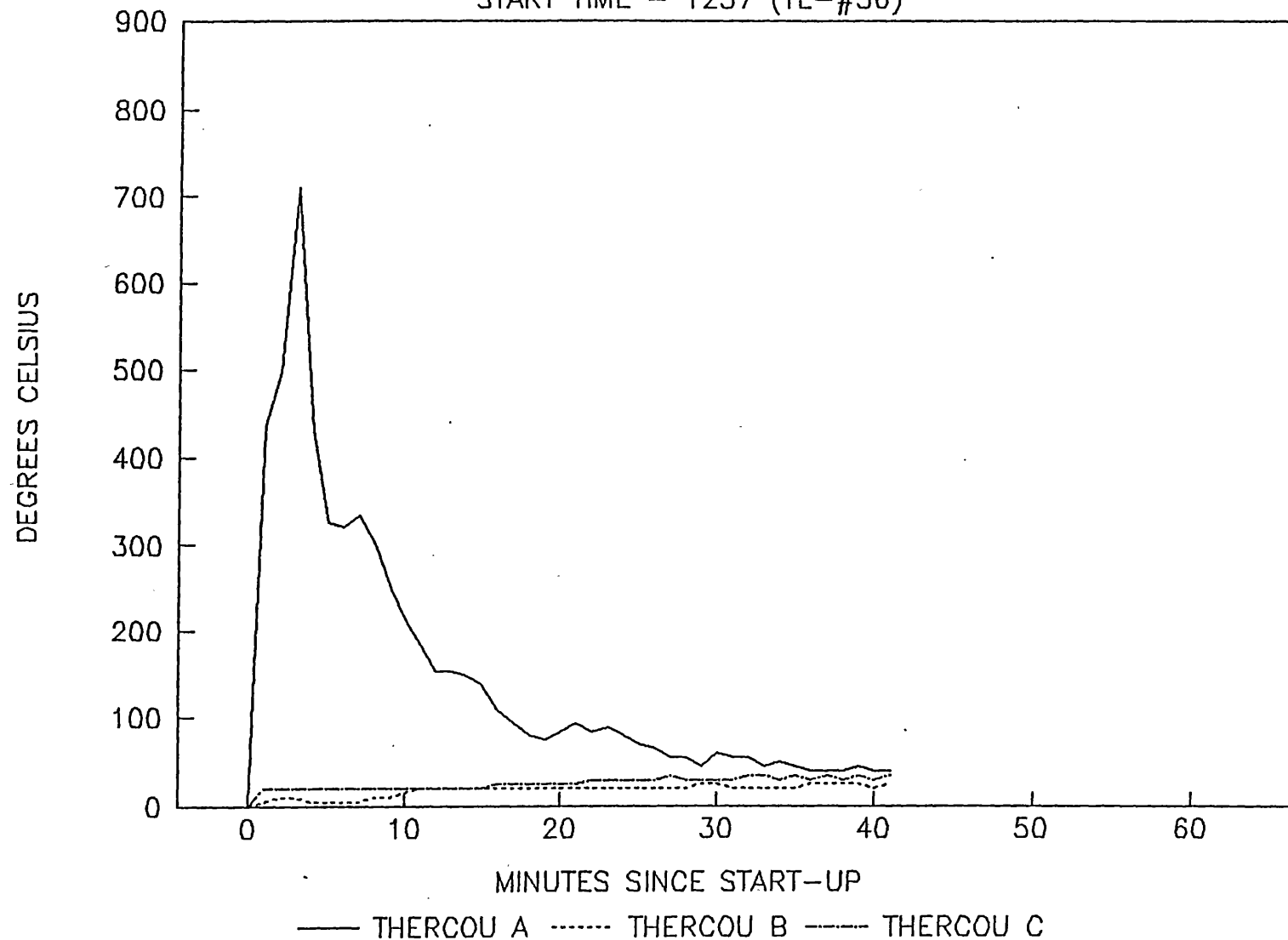
C: 18

D: 5



JACOBS WEST 9-19-90

START TIME - 1257 (TL-#36)



UNIT NAME: JACOBS BRANCH WEST

THERMOLOGGER #: 56

DEPTHS (MM)

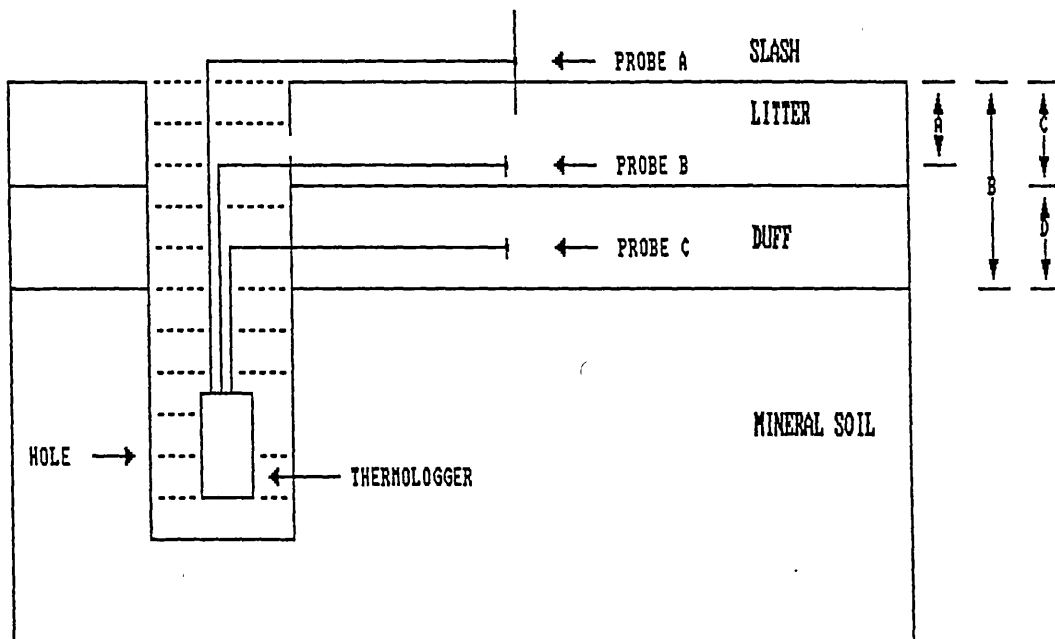
A: 18

COMMENTS:

B: 25

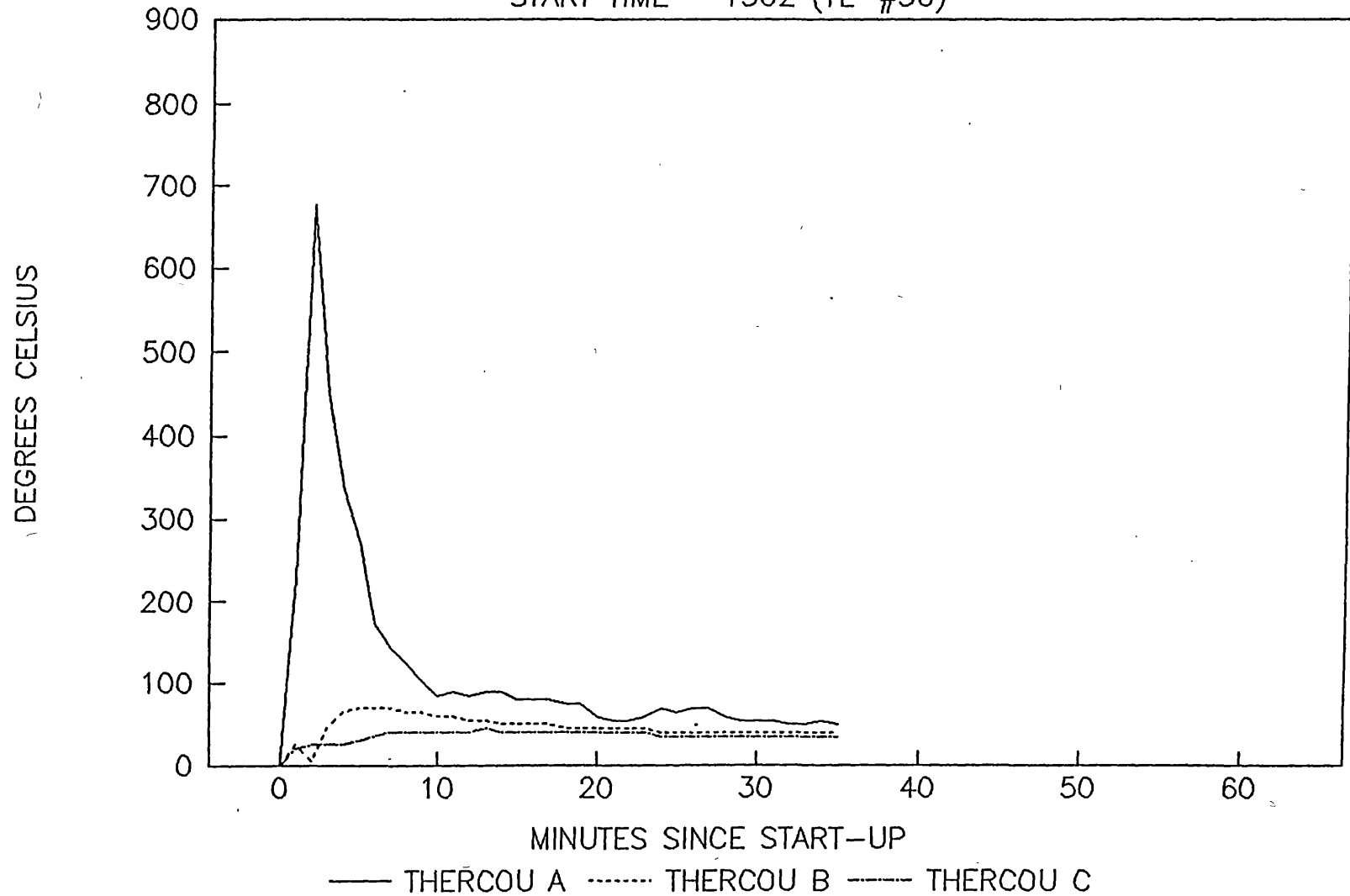
C: 15

D: 25



JACOBS WEST 9-19-90

START TIME - 1302 (TL-#56)



UNIT NAME: JACOBS BRANCH WEST

THERMOLOGGER #: 61

DEPTHS (MM)

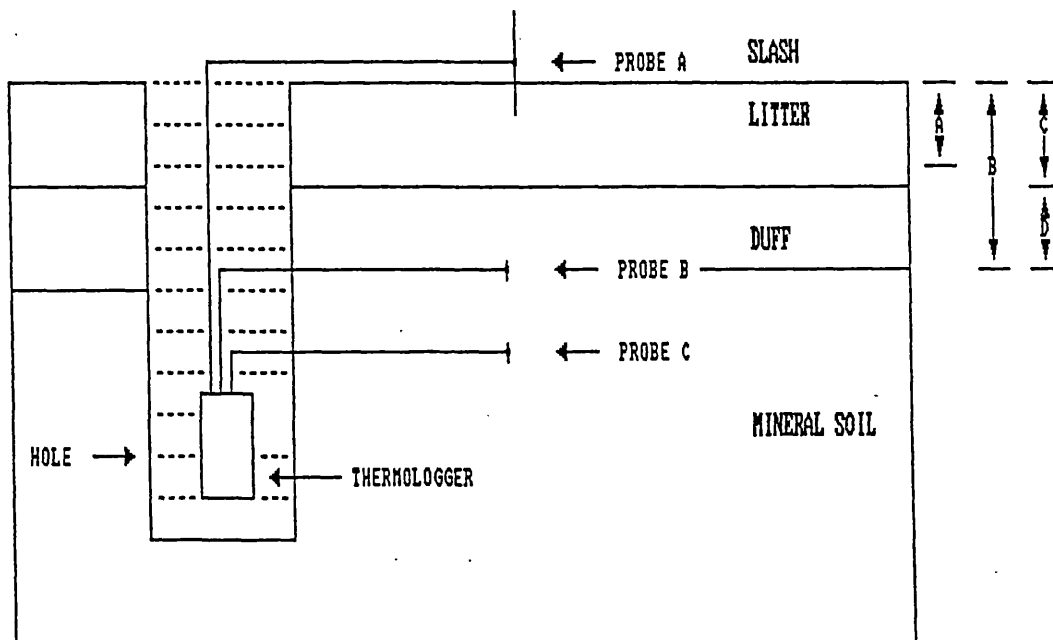
A: 32

COMMENTS: - PROBE 2 WAS LOCATED AT THE DUFF/MINERAL SOIL INTERFACE.

B: 57

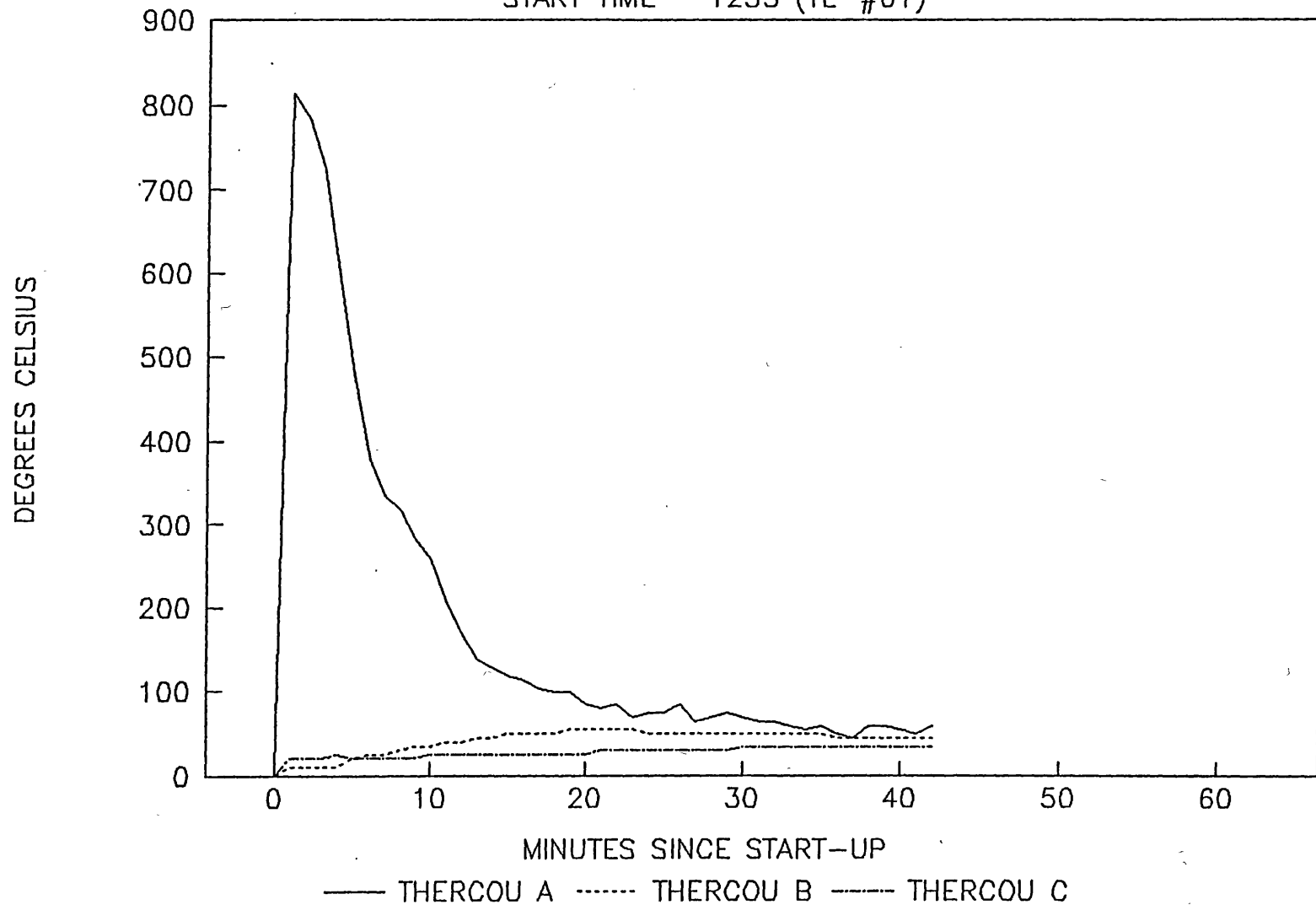
C: 8

D: 24



JACOBS WEST 9-19-90

START TIME - 1235 (TL-#61)



UNIT NAME: JACOBS BRANCH WEST

THERMOLOGGER #: 62

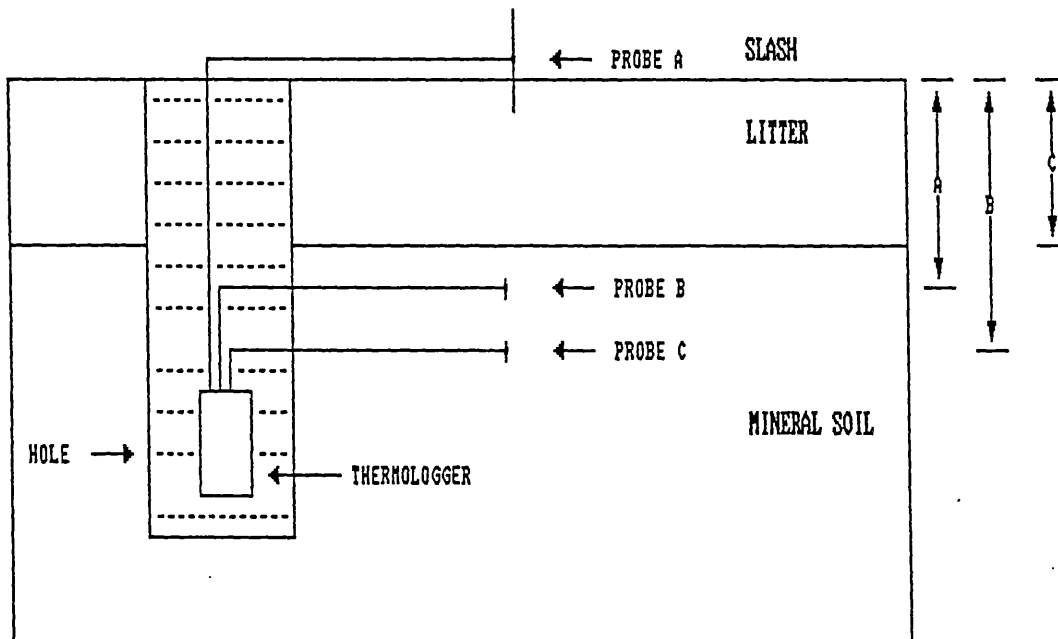
DEPTHS (MM)

A: 18

COMMENTS: - NO DUFF LAYER.

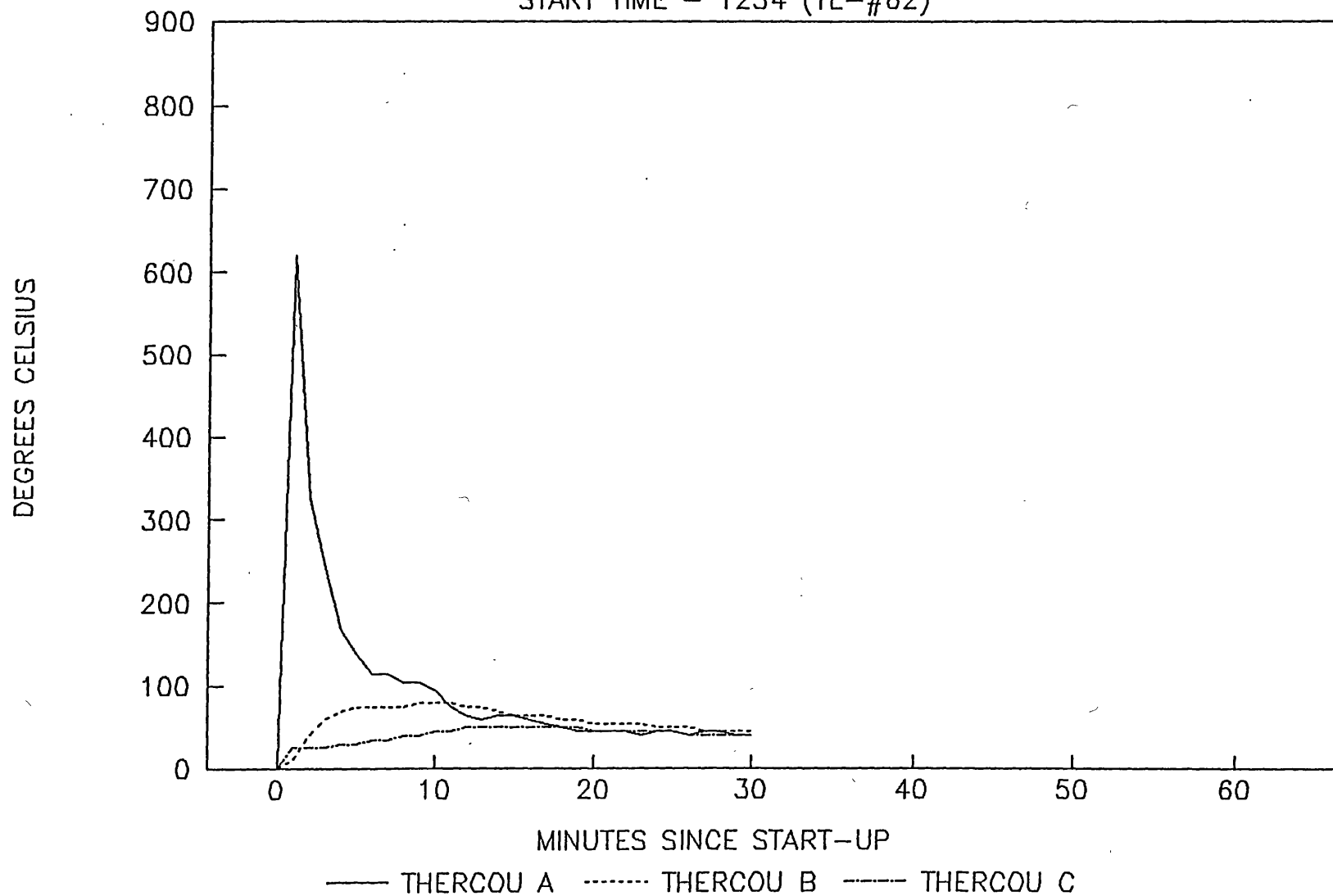
B: 38

C: 18



JACOBS WEST 9-19-90

START TIME - 1254 (TL-#62)



UNIT NAME: JACOBS BRANCH WEST

THERMOLOGGER #: 63

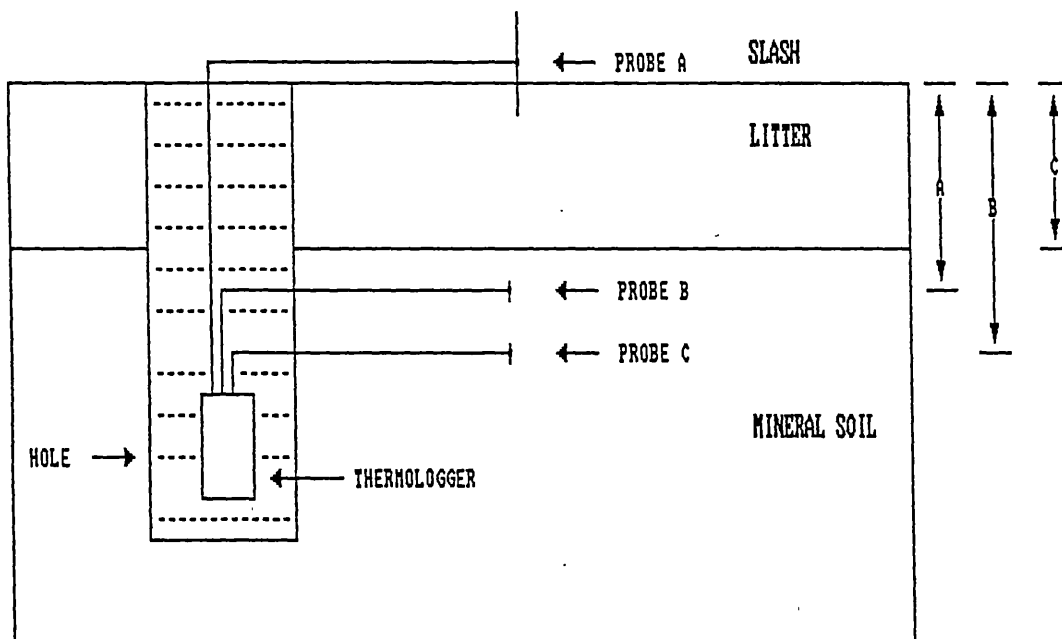
DEPTHS (MM)

A: 25

COMMENTS: - NO DUFF LAYER.

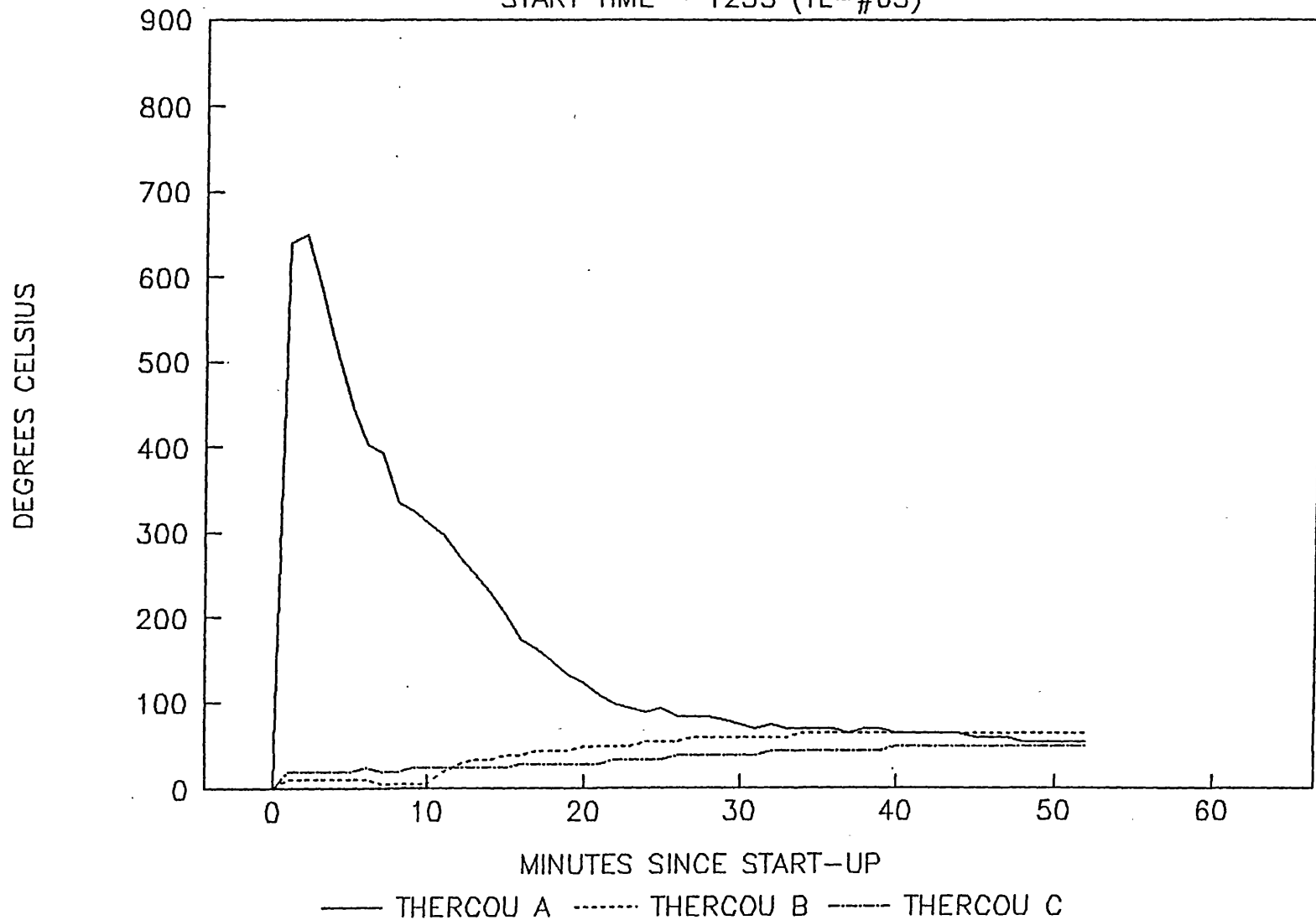
B: 35

C: 3



JACOBS WEST 9-19-90

START TIME - 1253 (TL-#63)



UNIT NAME: DEVILS DEN

THERMOLOGGER #: 32

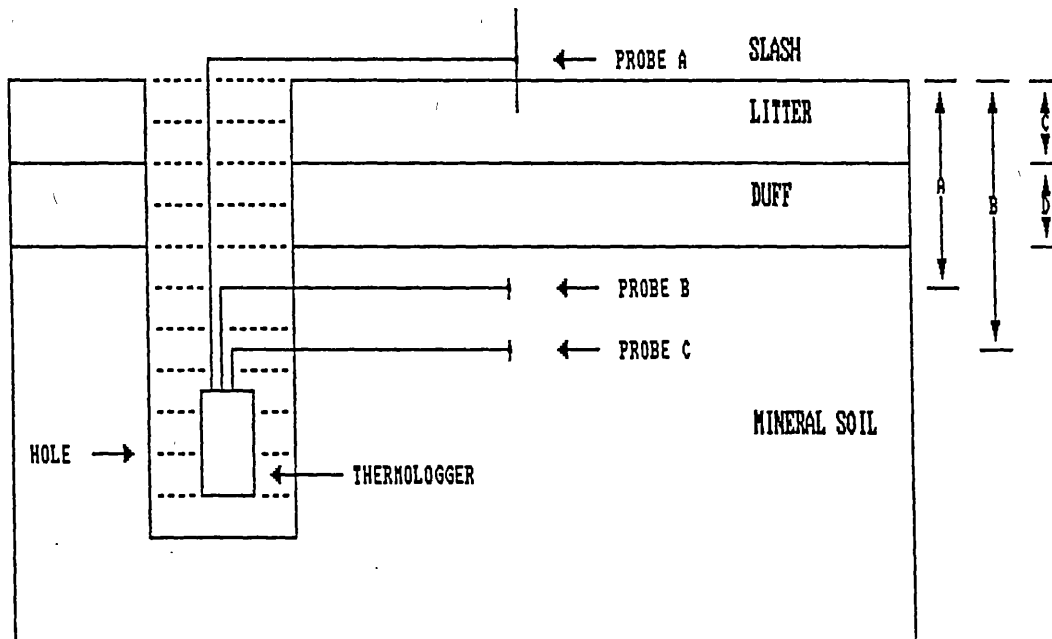
DEPTHS (MM)

A: 25 COMMENTS:

B: 45

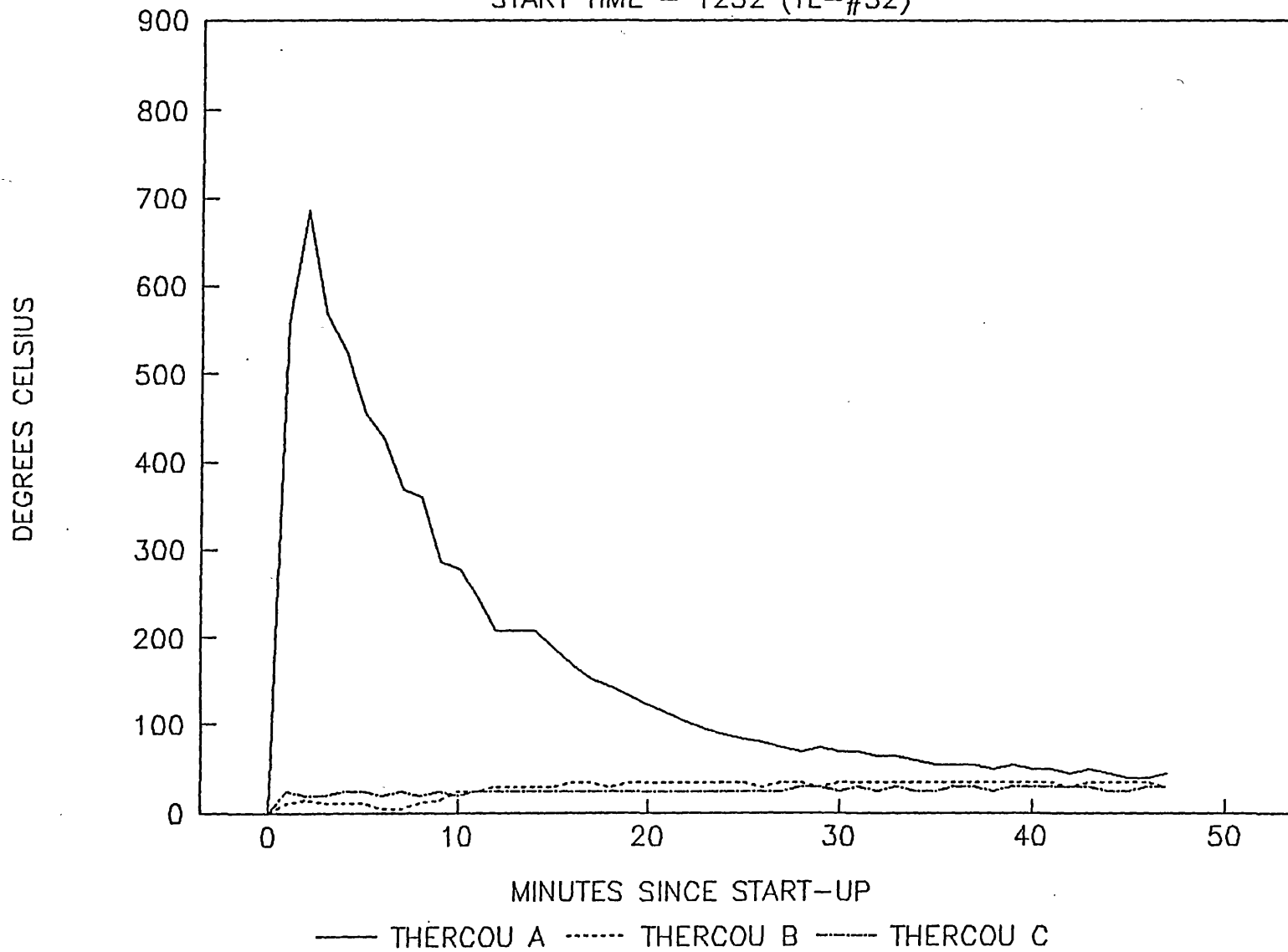
C: 5

D: 15



DEVILS DEN 9-21-90

START TIME - 1252 (TL-#32)



UNIT NAME: DEVILS DEN

THERMOLOGGER #: 35

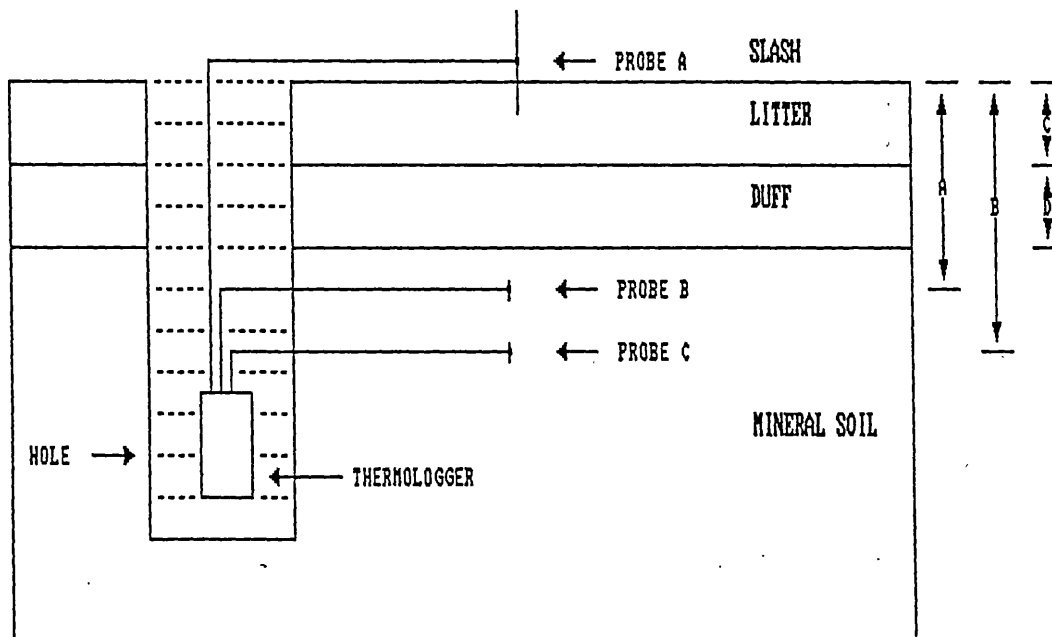
DEPTHS (MM)

A: 91 COMMENTS:

B: 131

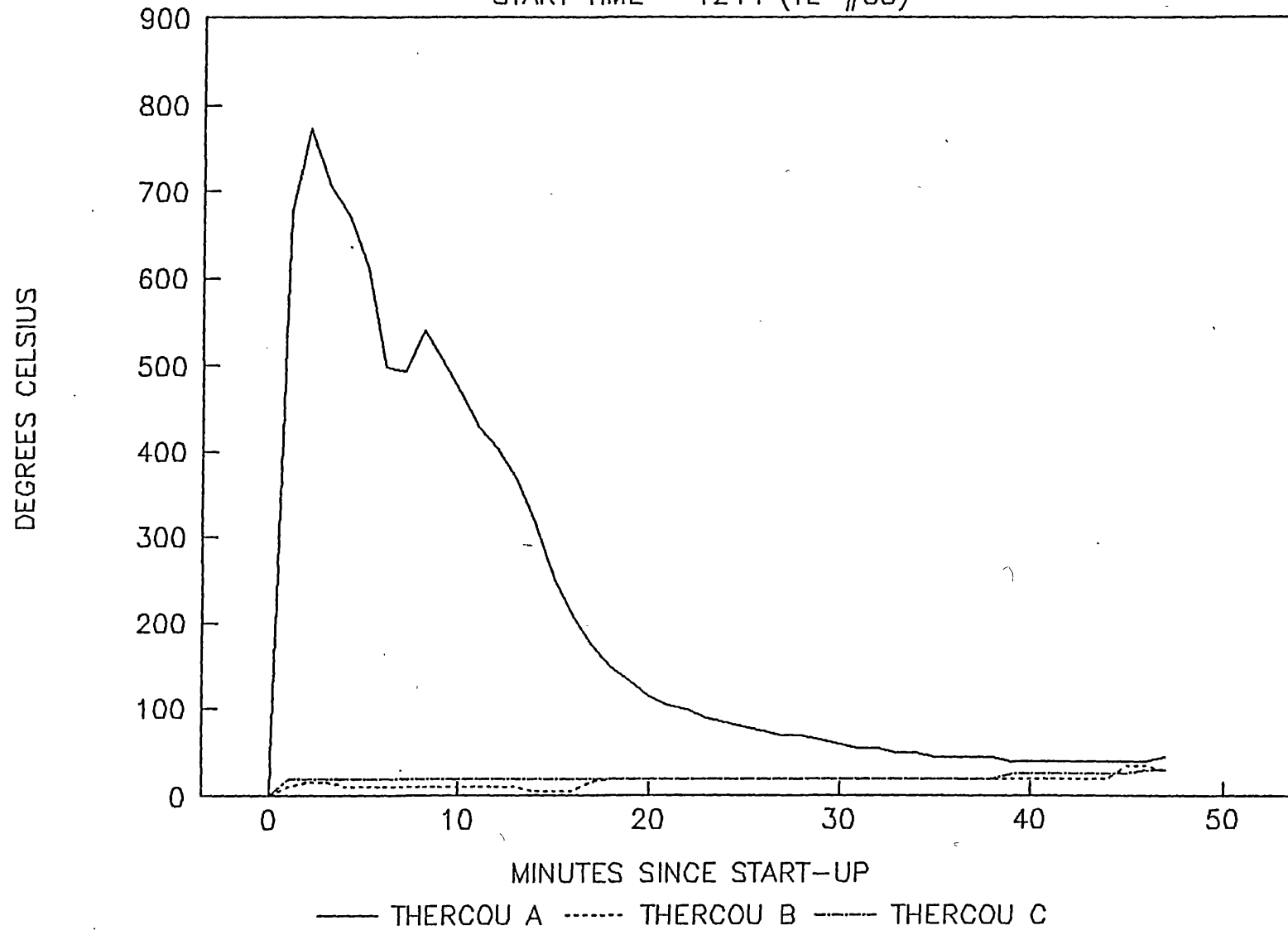
C: 37

D: 39



DEVILS DEN 9-21-90

START TIME - 1244 (TL-#35)



UNIT NAME: DEVILS DEN

THERMOLOGGER #: 57

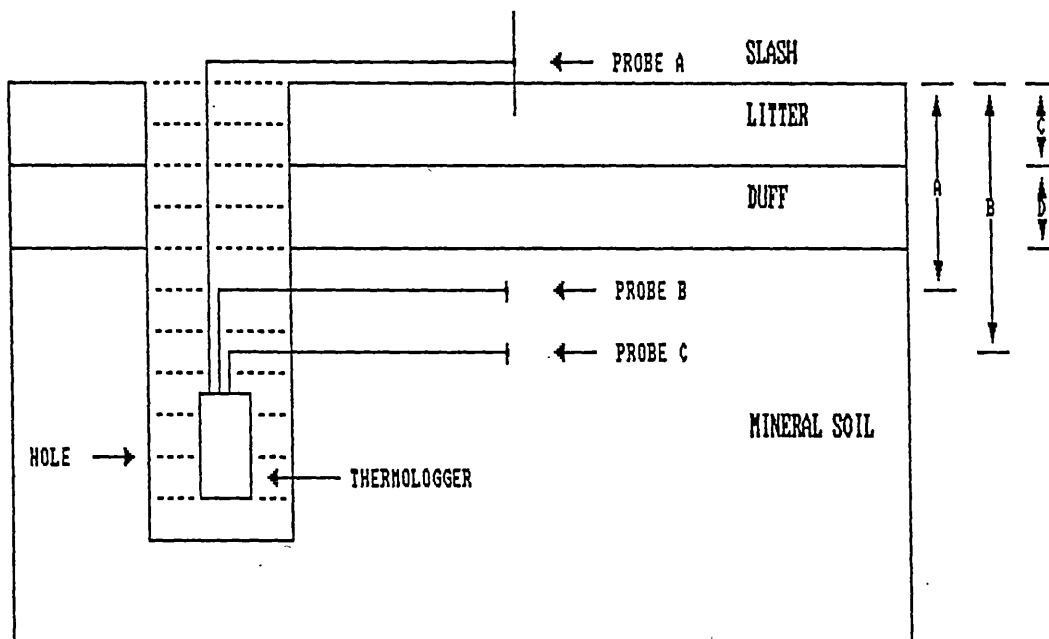
DEPTHS (MM)

A: 124 COMMENTS:

B: 154

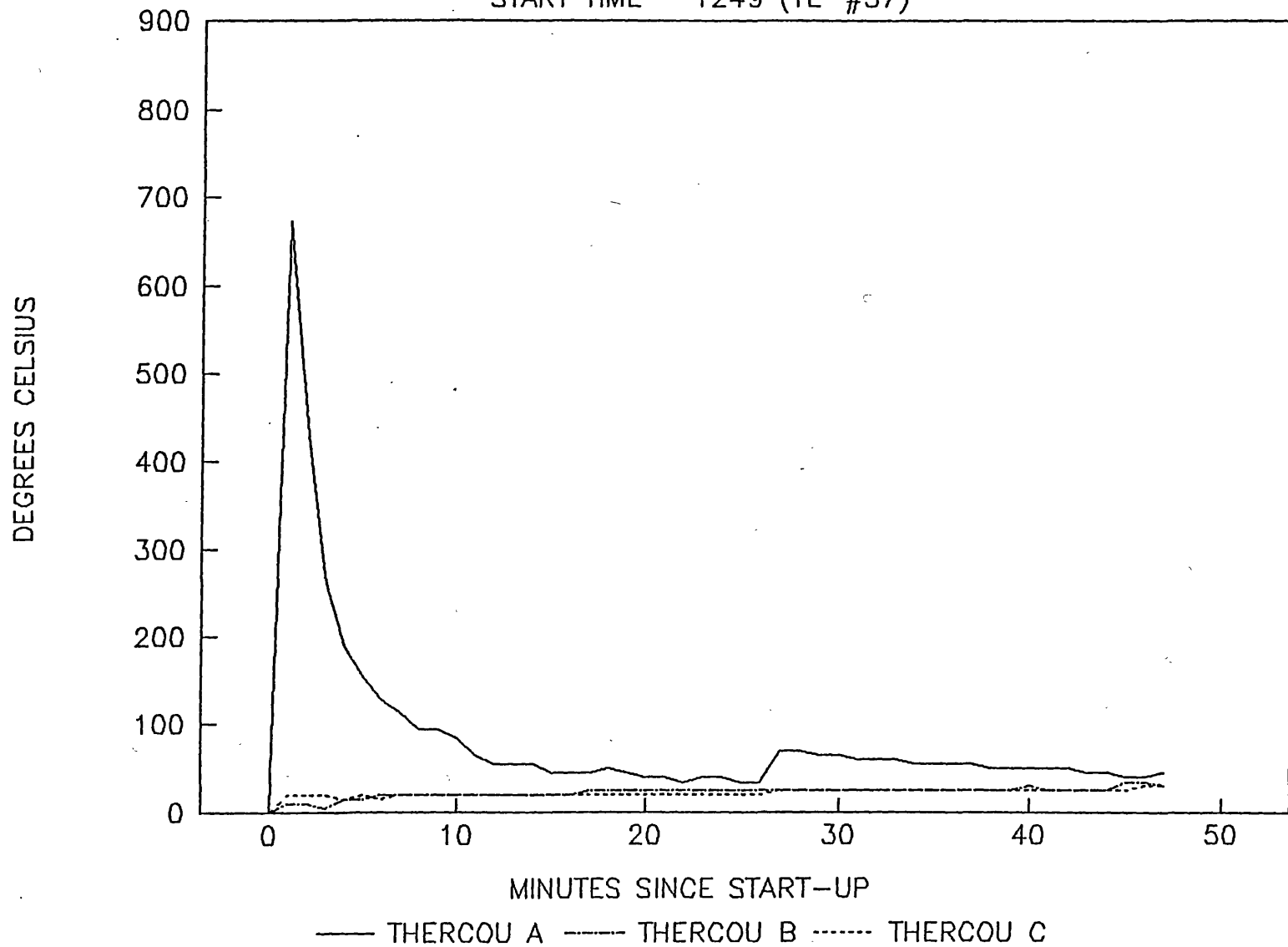
C: 34

D: 53



DEVILS DEN 9-21-90

START TIME - 1249 (TL-#57)



UNIT NAME: DEVILS DEN

THERMOLOGGER #: 62

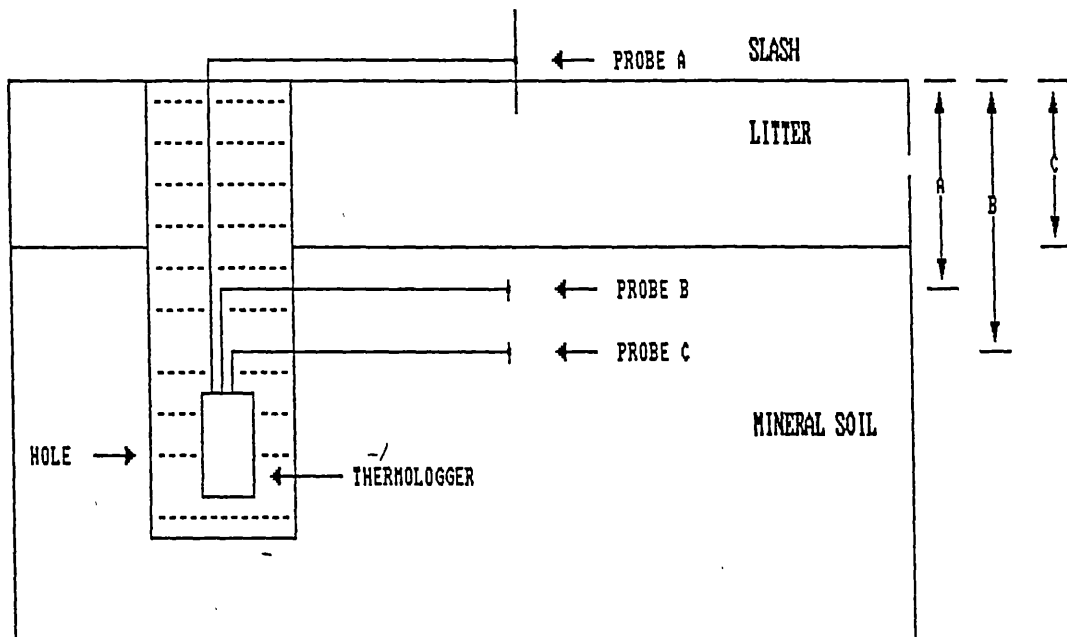
DEPTHS (MM)

A: 65

COMMENTS: - NO DUFF LAYER.

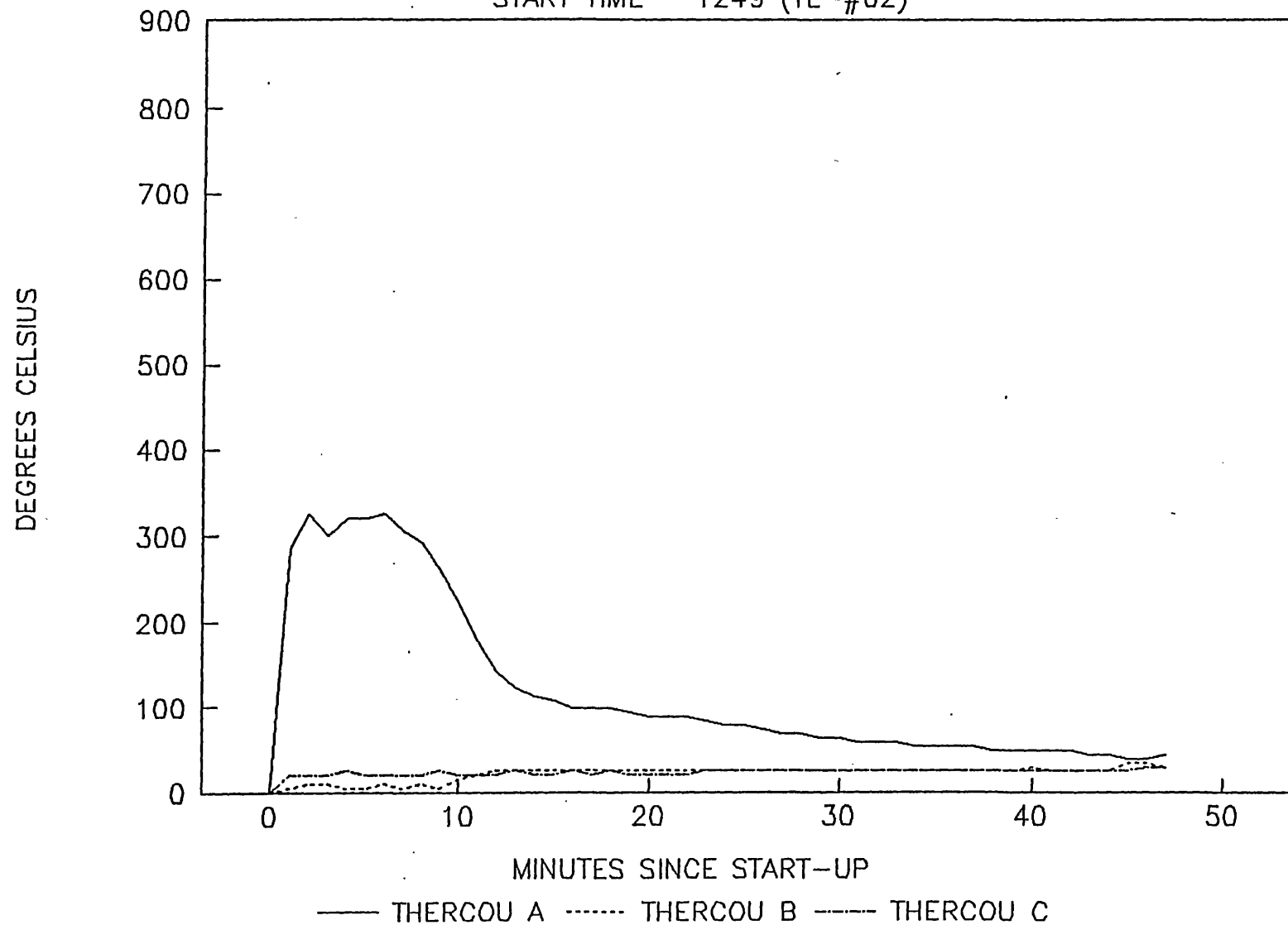
B: 98

C: 5



DEVILS DEN 9-21-90

START TIME - 1249 (TL-#62)



UNIT NAME: DEVILS DEN

THERMOLOGGER #: 63

DEPTHS (MM)

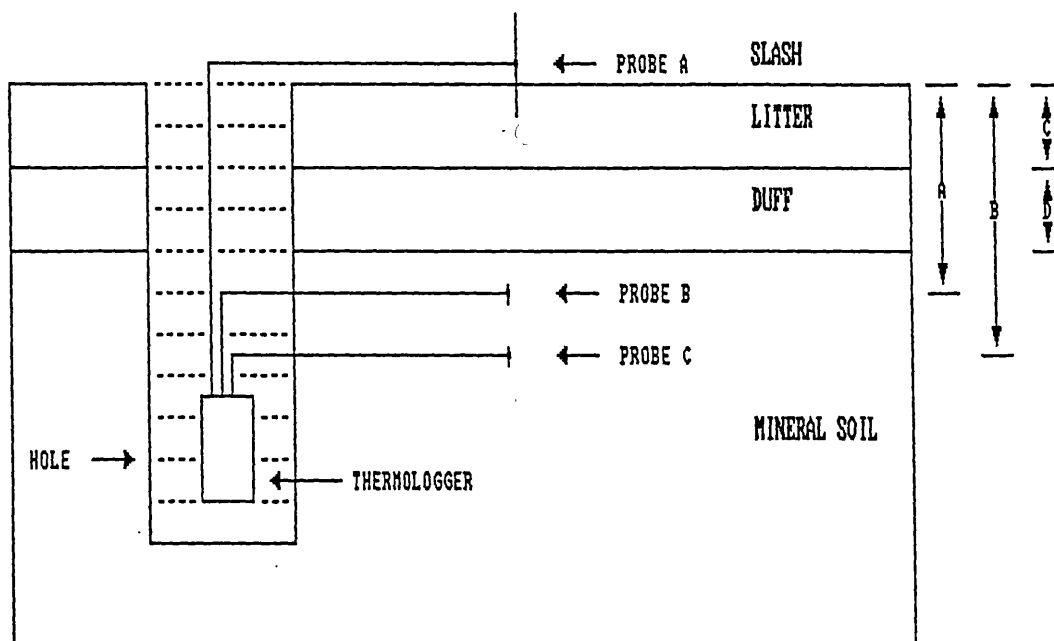
A: 169

COMMENTS:

B: 199

C: 19

D: 38



DEVILS DEN 9-21-90

START TIME - 1301 (TL-#63)

